# SEDAR 9
# SOUTHEAST DATA, ASSESSMENT AND REVIEW

Assessment of Vermilion Snapper, *Rhomboplites aurorubens*,
in the U.S. Gulf of Mexico

Stock Assessment Report 3

Section III. Assessment Workshop Report

Prepared by

SEDAR 9 Stock Assessment Panel

10 March 2006

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**III. Stock Assessment Workshop Report**
***(Developed by Assessment Workshop Panel)***

# 1. Introduction

## 1.1. Workshop Time and Place

The SEDAR 9 Assessment Workshop was held in Miami, FL, August 22 – 26, 2005.
A follow-up Assessment Workshop was held in Atlanta, GA, December 19-20, 2005

## 1.2. Terms of Reference

1. Select several appropriate modeling approaches, based on available data sources, parameters and values required to manage the stock, and recommendations of the Data Workshop.
2. Provide justification for the chosen data sources and for any deviations from Data Workshop recommendations.
3. Estimate stock parameters (fishing mortality, abundance, biomass, selectivity, stock-recruitment relationship, etc); include appropriate and representative measures of precision for parameter estimates and measures of model 'goodness of fit'.
4. Characterize uncertainty in the assessment, considering components such as input data, modeling approach, and model configuration.
5. Provide yield-per-recruit and stock-recruitment analyses.
6. Provide complete SFA criteria. This may include evaluating existing SFA benchmarks or estimating alternative SFA benchmarks (SFA benchmarks include MSY, Fmsy, Bmsy, MSST, and MFMT). Develop stock control rules.
7. Provide declarations of stock status relative to SFA benchmarks: MSY, Fmsy, Bmsy, MSST, MFMT.
8. Estimate Allowable Biological Catch (ABC) and provide an appropriate confidence interval.
9. Project future stock conditions and develop rebuilding schedules if warranted; include estimated generation time. Projections shall be developed in accordance with the following:
    - A) If stock is overfished:
        - F=0, F=current, F=Fmsy, Ftarget (OY),
        - F=Frebuild (max that rebuild in allowed time)
    - B) If stock is overfishing
        - F=Fcurrent, F=Fmsy, F= Ftarget (OY)
    - C) If stock is neither overfished nor overfishing
        - F=Fcurrent, F=Fmsy, F=Ftarget (OY)
10. Evaluate the results of past management actions and probable impacts of current management actions with emphasis on determining progress toward stated management goals.
11. Provide recommendations for future research and data collection (field and assessment); be as specific as practicable in describing sampling design and

sampling intensity. Prioritize recommendations based on their likelihood for improving stock assessment.

12. Fully document all activities: Draft Section III of the SEDAR Stock Assessment Report and provide complete tables of estimated values.
    Reports are to be finalized and distributed to the panel for review by September 30.
    Comments due to editors by October 14.
    Final version due to Coordinator by October 28.

## 1.3. List of Participants

### 1.3.1. Assessment Workshop I, August 22-26 2005

*Workshop Participants:*

Harry Blanchet................................................LA DWF/ GMFMC FSAP
Liz Brooks......................................................NMFS/SEFSC Miami, FL
Craig Brown....................................................NMFS/SEFSC Miami, FL
Shannon Calay ................................................NMFS/SEFSC Miami, FL
Guillermo Diaz................................................NMFS/SEFSC Miami, FL
Bob Dixon.......................................................NMFS/SEFSC Beaufort, NC
Bob Gill...........................................................GMFMC Advisory Panel
George Guillen................................................Univ. Houston Clear Lake/GMFMC SSC
David Hanisko ................................................NMFS/SEFSC, Pascagoula MS
Walter Ingram .................................................NMFS/SEFSC Pascagoula MS
Bob Muller......................................................FL FWCC/GMFMC SSC
Debra Murie....................................................University of Florida/GMFMC FSAP
Josh Sladek Nowlis..........................................NMFS/SEFSC Miami, FL
Scott Nichols...................................................NMFS/SEFSC Pascagoula MS
Dennis O'Hern................................................GMFMC Advisory Panel
Larry Perruso ..................................................NMFS/SEFSC Pascagoula MS
Steven Saul......................................................RSMAS/ SEFSC Miami FL
Jerry Scott .......................................................NMFS/SEFSC Miami, FL
Steve Turner....................................................NMFS/SEFSC Miami, FL

*Observers:*

Kay Williams ..................................................GMFMC
Elizabeth Fetherston........................................Ocean Conservancy
Albert Jones .....................................................GMFMC SSC

*Staff:*

John Carmichael..............................................SEDAR
Stu Kennedy.....................................................GMFMC
Dawn Aring......................................................GMFMC
Patrick Gilles...................................................NMFS/SEFSC Miami FL

### 1.3.2. Assessment Workshop II, December 19-20 2005

*Workshop Participants:*

Liz Brooks......................................................NMFS/SEFSC Miami, FL
Craig Brown...................................................NMFS/SEFSC Miami, FL
Shannon Calay ...............................................NMFS/SEFSC Miami, FL
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## 1.4. List of Assessment Workshop Working Papers, Assessment Workshop I & II

| | | |
|---|---|---|
| SEDAR9-AW1 | Incorporating age information into SEAMAP trawl indices for SEDAR9 species | Nicholls, S. |
| SEDAR9-AW2 | Separating Vermilion Snapper Trawl Indexes into East and West Components | Nicholls, S |
| SEDAR9-AW3 | Modeling Shrimp Fleet Bycatch for the SEDAR9 Assessments | Nicholls, S |
| SEDAR9-AW4 | Status of the Vermilion Snapper (*Rhomboplites Aurorubens)* Fisheries of the Gulf of Mexico | Cass-Calay, S. |
| SEDAR9-AW5 | Gulf of Mexico Greater Amberjack Stock Assessment | Diaz, Guillermo A., and Elizabeth Brooks |
| SEDAR9-AW6 | A Categorical Approach to Modeling Catch at Age for Various Sectors of the Gray Triggerfish (*Balistes Capriscus)* Fishery in the Gulf of Mexico | Saul, Steven and G. Walter Ingram, Jr. |
| SEDAR9-AW7 | Updated Fishery-Dependent Indices of Abundance for Gulf of Mexico Gray Triggerfish (*Balistes Capriscus)* | Nowlis, Joshua Sladek |
| SEDAR9-AW8 | An Aggregated Production Model for the Gulf of Mexico Gray Triggerfish (*Balistes Capriscus)* Stock | Nowlis, Joshua Sladek and Steven Saul |
| SEDAR9-AW9 | Age-Based Analyses of the Gulf of Mexico Gray Triggerfish (Balistes capriscus) Stock | Nowlis, J. S. |
| SEDAR9-AW10 | Gulf of Mexico greater amberjack virtual population analysis assessment | Brown, C. A.,C. E. Porch, and G. P. Scott |
| SEDAR9-AW11 | Rebuilding Projections for the Gulf of Mexico Gray Triggerfish (Balistes capriscus) Stock. | Nowlis, J. S. |

# 2. Data Review and Update

Input data are discussed and tabulated within the detailed sections for each model (Sections 3.1 and 3.2). Deviations from SEDAR9-DW recommendations are noted.

# 3. Stock Assessment Models and Results

Two types of models were used to assess the status of vermilion snapper in the U.S. Gulf of Mexico, a state-space implementation of the Pella-Tomlinson (P-T) non-equilibrium surplus production model (Porch, 2001), and a state spaced age-structured production model (Porch, 2002a). The P-T production model is presented as a continuity case, and is intended to replicate the previous assessment (Porch and Cass-Calay, 2001).

## 3.1. Model 1: Continuity Case-Pella-Tomlinson Production Model

### 3.1.1. Pella-Tomlinson Production Model Methods

#### *3.1.1.1. Overview*

The P-T production model was used to replicate the previous assessment (Porch and Cass-Calay, 2001), and requires the following assumptions: 1) that there is a single unit stock, 2) that all age classes have the same average fecundity, and 3) that all age classes are equally vulnerable to fishing. These assumptions seem plausible for vermilion snapper of reproductive age (age 1 and older) because the growth curve is relatively flat and the variance in size-at-age is large.

The base model of the previous assessment (2001) used the P-T production model to obtain estimates of population abundance and mortality rates using data from 1986 - 1999.

#### *3.1.1.2. Data Sources*

Available data inputs were used as provided by the SEDAR9 Data Workshop (SEDAR 9: Vermilion Snapper Data Workshop Report). Three catch series (Commercial, Recreational and Shrimp Bycatch), one effort series (Shrimp Bycatch) and two indices of abundance (Commercial-Handline and Headboat East) were considered. The catch and effort series are summarized in Table 3.1.1.2.1. Indices of abundance are summarized in Table 3.1.1.2.2.
The effort series for the shrimp fleet was provided by the SEDAR7 (Red Snapper) data workshop, and is discussed in document SEDAR7-DW-24.

No attempt was made to model the dead discards of the recreational and commercial fisheries. In other words, release mortality was assumed to be negligible.

### *3.1.1.3. Model Configuration and Equations*

*The following description of the Pella-Tomlinson production model is excised (with permission of the author) from the description by Porch (2001).*

The Pella-Tomlinson (1969) generalized production model may be written in the form

$$\frac{dB}{dt} = rB\left(1-\left(B/k\right)^{m-1}\right) - FB \quad (1)$$

where $B$ denotes biomass, $r$ is the intrinsic rate of increase, $k$ is the carrying capacity, $F$ is the fishing mortality rate, and $m$ is the exponent controlling the inflection point of the production curve. There is no general analytical solution for this differential equation, although analytic solutions exist for specific values of $m$ (e.g., the classic Schaeffer model with $m$=2). The present algorithm uses the semi-implicit difference approximation suggested by Otter Research Ltd. (2000),

$$B_{t+\delta} = \frac{B_t(1+r\delta)}{1+(r(B_t/k)^{m-1}+F_t)\delta} \quad (2)$$

Tests comparing this approximation with the exact solution for $m$=2 indicate it is accurate to several significant digits with $\delta$ = 1/16 yr.

The process and observation equations are summarized in Table 3.1.1.3.1. Process errors in the state variables and observation errors in the data variables were accommodated using the first-order autoregressive (AR1) model

$$\begin{aligned} g_{t+1} &= \mathrm{E}[g_{t+1}]\, e^{\varepsilon_{t+1}} \\ \varepsilon_{t+1} &= \rho\varepsilon_t + a_{t+1} \end{aligned}, \quad (3)$$

where $g$ represents any given state or observation variable, $a$ is a normal-distributed random error with mean 0 and standard deviation $\sigma_g$, and E[$g$] denotes the expected value of $g$ given by the deterministic components of the process or observation equations in Table 3.1.1.3.1. In the case of data, the $g_t$ in Eq. 3 correspond to observed quantities, but in the case of states the $g_t$ are unobserved and must be estimated along with the parameter vector. For stability reasons, it is assumed that $\varepsilon_0$ = 0, leading to the negative log-density

$$-\log \mathrm{P}(g\,|\,\Theta,\mathbf{X}) = \frac{1}{2\sigma_g^2}\left[(\ln g_1 - \ln \mathrm{E}[g_1])^2 + \sum_{t=1}^{N-1}(\ln g_{t+1} - \ln \mathrm{E}[g_{t+1}] - \rho\ln g_t + \rho\ln \mathrm{E}[g_t])^2\right] + N\log\sigma_g\,, \quad (4)$$

where $\rho_g$ is the correlation coefficient and $\sigma_g^2$ is the variance of log(a). In the present model, variances of the process and observation errors are parameterized as multiples of an overall variance parameter $\sigma^2$, i.e., $\sigma_g^2 = V_g\sigma^2$. Note that the 'random walk' model of Fournier et al. (1998) is merely a special case of Eq. 4 with $\rho = 1$ and $E[g_t] = g_0$ (a time-invariant parameter).

Catch and effort series were assumed to be lognormally distributed. The shrimp bycatch is poorly known and was assigned a relatively high coefficient of variation (CV) of 1.0, whereas the shrimp effort was assumed to be somewhat better known and assigned a CV of 0.5 The recreational catches were assigned CV's equal to the MRFSS estimates (CV $\cong$ 0.15). The commercial catch, which is based on a census, was assumed to have relatively low CV of 0.1.

Estimates of the CVs of the two CPUE series are available from GLM results, but are unrealistically small as they reflect only the uncertainty in measuring CPUE rather than the uncertainty that CPUE reflects abundance. Accordingly, the two indices were assigned equal CVs in each year, and that value was estimated within the production model. In effect, this is equivalent to equally weighting the indices.

The model was implemented using the nonlinear optimization package AD Model Builder (Otter Research Ltd., 2000).

### *3.1.1.4. Parameters Estimated*

The parameters estimated in P-T production model include three catchability coefficients ($q_f$, one for each fishery, f), three sets of effort parameters ($E_{fy}$), the initial biomass ($B_{1986}$), carrying capacity (k) and the intrinsic rate of increase (r). For the continuity case, the production exponent was fixed at m = 2 (Schaeffer type model). The state variables r, k and $q_f$ were estimated as described in Table 3.1.1.4.1; no inter-annual variability was allowed. The annual effort parameters were assumed to be lognormally distributed about the overall mean of the series with a relatively large process error (CV = 0.5). A penalty was also incorporated that prevented MSY from being greater than the largest catch in the series.

### *3.1.1.5. Uncertainty and Measures of Precision*

Parameter uncertainty was addressed by estimating process and observation errors. A complete description of the equations used can be found in a previous section, Section 3.1.1.3.

### *3.1.1.6. Benchmark / Reference points methods*

Reference points and benchmarks were calculated with regard to maximum sustainable yield (MSY). Since the production exponent was fixed at 2.0, the model is a Schaeffer type model, and $B_{MSY}$ occurs at k/2.

### *3.1.1.7. Projection methods*

Projections were run replicating the methods of the 2001 assessment base model projections. Each projection was calculated from 2005 to 2016. Fishing mortality during 2005 and 2006 was assumed to be equal to the 2004 level. Four types of projections are presented; (1) constant fishing mortality ($F_{2004}$) projected through 2016, (2) fishing at $F_{MSY}$ from 2007-2016, (3) fishing at the constant F that allows recovery in 2014, and (4) fishing at the constant yield that allows recovery in 2014. Projections 3 and 4 were intended to address the recovery plan imposed by Amendment 23 which stipulates recovery of the Gulf stock of vermilion snapper by 2014.

These projections are identical to those run during the 2001 assessment, except the recovery target year was 2011, and $F_{2000}$ and $F_{2001}$ were assumed equal to $F_{1999}$ for the 2001 projections.

### 3.1.2. Pella-Tomlinson Production Model Results

#### *3.1.2.1. Measures of Overall Model Fit*

The likelihood statistics of the P-T model are as follows:

| | |
|---|---|
| AIC: | -1.64e+02 |
| AICc (small sample): | 2.35e+01 |
| Objective Function: | -1.45e+02 |

Generally, the performance of the P-T production model was adequate. Fits to the catch series and summarized in Fig. 3.1.2.1.1 and Table 3.1.2.1.1. For the directed fleets, predicted values rarely deviated from the observations by more than 20%. The fits to the shrimp bycatch were poor; deviations averaged 20-50%. However, this was not unexpected since a CV of 1.0 was used for the shrimp bycatch and CVs of 0.1 were used for the other catch series.

Fits to the shrimp effort series (Fig. 3.1.2.1.2 and Table 3.1.2.1.2), and indices of abundance (Fig. 3.1.2.1.3 and Table 3.1.2.1.3) were acceptable, although deviations were generally larger than those of the catch series. The recent improvement in catch rates implied by the commercial handline index was not reflected in the fit of the P-T model (Fig. 3.1.2.1.3).

#### *3.1.2.2. Parameter estimates*

The parameter estimates obtained from the P-T model continuity case are summarized in Table. 3.1.2.2.1.

#### *3.1.2.3. Stock Biomass*

The continuity run of the P-T production model estimated $B_{MSY}$ at 10.8 million pounds. Results indicate that the biomass of vermilion snapper was below $B_{MSY}$ during the initial year (1986), and remained so throughout the time series. In 1986, $B/B_{MSY}$ was 0.74. The population status improved somewhat between 1986 and 1992, and then generally declined to a series minimum of 0.40 in 2004 (Fig. 3.1.2.3.1 and Table 3.1.2.3.1).

To facilitate comparison, the results of the 2001 base case and 2005 continuity case are overlaid in Figure 3.1.2.3.1. The population biomass estimates of the continuity case are very similar to the base case used during the previous assessment.

#### *3.1.2.4. Fishing Mortality*

The annual estimates of fishing mortality are summarized in Figure 3.1.2.4.1 and Table 3.1.2.4.1. The continuity run of the P-T production model estimated $F_{MSY}$ at 0.33. According to the continuity run, F in the initial year was above $F_{MSY}$ ($F_{1986}/F_{MSY}$ = 1.2), then declined to a level near $F_{MSY}$ until 1989. After 1989, F increased rapidly to values substantially above $F_{MSY}$. The fishing mortality rate remains above $F_{MSY}$ through 2004. In 2004, F is estimated at 0.90 ($F_{2004}/F_{MSY}$ = 2.7), the highest value in the time series.

The estimated fishing mortality rates from the continuity case are very similar to the base case used during the previous assessment (Figure 3.1.2.4.1.)

#### *3.1.2.5. Measures of Parameter Uncertainty*

Parameter uncertainty was addressed by estimating process and observation errors. The standard deviations of the estimated parameters are summarized in a previously cited table, Table 3.1.2.2.1.

#### *3.1.2.6. Retrospective and Sensitivity Analyses*

As this was intended to be a continuity case, no retrospective or sensitivity analyses were preformed. This model was intended to determine the effect of 5 additional years of data and updated data series on the estimated population benchmarks and reference points. This model was also constructed for comparison with a new age-structured approach (SSASPM) to be discussed in subsequent sections.

#### *3.1.2.7. Benchmarks / Reference Points*

The benchmarks and reference points estimated by the P-T production model continuity case and the 2001 base model are summarized in Table 3.1.2.7.1. According to the P-T production model continuity case, the 2004 population status is overfished ($B_{2004}/B_{MSY}$ = 0.40) and overfishing is ongoing ($F_{2004}/F_{MSY}$ = 2.7). This result is similar to the previous assessment ($B_{1999}/B_{MSY}$ = 0.36; $F_{1999}/F_{MSY}$ = 2.0).

#### *3.1.2.8. Projections*

Four projection scenarios were considered for the continuity case. These replicated the projections run for the 2001 vermilion snapper assessment, and are summarized in Figure 3.1.2.8.1 and Table 3.1.2.8.1.

If $F_{2004}$ (0.90) is projected through 2016, the population declines steeply, reaching 1.8% of $B_{MSY}$ in 2016. Projected yield declines as well, dropping to less than 200,000 lbs by 2016.

If the population is projected at $F = F_{MSY}$ during 2007-2016, the population biomass recovers to 79% of $B_{MSY}$ by 2016. Yield initially declines ($Y_{2004}$ = 3.4 million pounds while $Y_{2007}$ is projected to equal 677,000 lbs), but recovers to 81% of MSY (2.9 million lbs) by 2016.

Amendment 23 stipulates that vermilion snapper are overfished, and mandates a 10 year recovery plan. Two projections were run to examine this recovery scenario. For the first, fishing mortality was held constant from 2007-2014, at the value predicted to achieve recovery by 2014 (F = 0.222). This strategy achieves recovery, but requires substantial reductions in yield, particularly during 2007 and 2008. By 2016, yield has recovered to 80% of MSY (2.9 million pounds). Another method to achieve recovery to $B_{MSY}$ by 2014 is to restrict yield. The final projection demonstrates that dramatic reductions in yield are required. A constant yield of 887,000 lbs from 2007 to 2014 allows recovery to $B_{MSY}$ in 2014.

The projections from the 2001 assessment of vermilion snapper are also summarized in Figure 3.1.2.8.1. The results of the continuity case are quite consistent with the previous model, although more pessimistic. According to the continuity case, fishing at $F_{2004}$ (0.9) will cause the extinction of the population by ~2020. The less favorable projections are primarily due to the high fishing mortality rates observed during 2000-2004. They are the highest on record.

## 3.2. Model 2: State-Space Age-Structured Production Model (SSASPM)

### 3.2.1. SSASPM Methods

#### *3.2.1.1. Overview*

The state-space age-structured production model (SSASPM) is thoroughly described by Porch (2002). SSASPM has several advantages over a non-equilibrium production model, such as the Pella-Tomlinson. SSASPM accommodates age-varying fecundity, natural mortality and selectivity functions. In addition, age composition data can be used to provide additional information to minimize the objective function, and to estimate the selectivity of the directed fleets. The current version of SSASPM assumes a single unit stock.

#### *3.2.1.2. Data Sources*

SSASPM runs specified four directed fleets (Commercial-East, Commercial-West, Recreational and Shrimp-Bycatch) and five indices of abundance (Commercial-Handline-East, Commercial-Handline-West, Headboat-East, Headboat-West, and MRFSS-East). Three age composition matrices (number-at-age by year) were used (Commercial-East, Commercial-West and Recreational) to allow estimation of selectivity vectors. Age composition was determined from otolith observations made by the NOAA Fisheries, Panama City Laboratory, and reported in SEDAR9-DW-02.

Available data inputs were used as provided by the SEDAR9 Data Workshop (SEDAR 9: Vermilion Snapper Data Workshop Report) with the exception of the length-weight equation. The SEDAR9 length-weight equation (5):

$$TW\ (kg) = 2E\text{-}08 * TL(mm)^{2.98} \qquad (5)$$

was found to differ substantially from the relationship predicted using TIP data (Figure 3.2.1.2.1). Therefore, the length-weight equation reported by Hood and Johnson (1999) was substituted (rewritten as a power function in mm and kg),

$$W(kg) = 2.51E\text{-}08 * TL^{2.87} \qquad (6)$$

where $W$ is whole weight in kg and $TL$ is the total length in mm. The Hood and Johnson (1999) equation was also used during the 2001 vermilion snapper assessment, and was found to be more consistent with the available TIP observations (Figure 3.2.1.2.1).

The growth (Figure 3.2.1.2.2) and fecundity (Figure 3.2.1.2.3) functions were fixed at the values described in the SEDAR9 Data Workshop Report. Natural Mortality was fixed at 0.25 for all ages.

As suggested by the Data Workshop panel, steepness was estimated using a lognormal prior (mean = 0.6; variance = 0.85) such that there is a <10% chance than steepness exceeds 0.9.

The most recent estimate of shrimp trawl bycatch of vermilion snapper is 9.2 million fish annually[1]. According to Porch and Cass-Calay (2001), the length-distribution obtained from the NMFS observer program is bimodal, and suggests that approximately 25 % of the vermilion snapper landed by the shrimp fleet are age-0 and the remainder are at least age-1. Because SSASPM does not accommodate age-0, the shrimp bycatch estimate was multiplied by the proportion of fish expected to be at least age-1 (9.2 million * 0.75 = 6.9 million fish). Shrimp bycatch was modeled using a fixed selectivity (100% vulnerability at age-1, 30% at age-2, 3% at age-3 and 0% at ages 4-14+).

Input data for the SSASPM model are summarized in Table 3.2.1.2.1 (catch series), Table 3.2.1.2.2 (indices) and Table 3.2.1.2.3. (age composition).

[1] Nichols, S. Personal Communication. NOAA Fisheries, Pascagoula Laboratory. Scott.Nichols@noaa.gov

The data input file for the SSASPM base model is included as Table. 3.2.1.2.4

### 3.2.1.3. Model Equations

Model equations are excised (with permission of the author) from the SEDAR-9-RW supplementary document Porch (2003).

The abundance of each age class is computed at monthly intervals according to the formula

$$N_{a,y,m+1} = N_{a,y,m}\, e^{-M_a \delta} - \sum_{i} C_{a,y,m,i} \tag{7}$$

where $N_{a,y,m}$ is the number of fish in age class $a$ at the beginning of month $m$ in year $y$, $C_{a,y,m,i}$ is the catch in numbers of fleet $i$, $M$ is the natural mortality rate coefficient ($yr^{-1}$)and $d$ is the duration of the time step in years (= 1/12).

The abundance at the beginning of the first month is modeled as

$$N_{a,y+1,1} = \begin{cases} \dfrac{4hS_{y-\alpha}}{\theta_0(1-h) + S_{y-\alpha}(5h-1)/R_0} & a = \alpha \\ N_{a-1,y,13} & \alpha < a < A \\ N_{A-1,y,13} + N_{A,y,13} & a = A \end{cases} \tag{8}$$

where the subscript 13 denotes the end of the 12th month (beginning of the next year). Note that the initial abundance of the youngest age class ($a$) is modeled by the Beverton and Holt (1957) function of spawning biomass ($S$) recast in terms of virgin recruitment $R_0$, virgin spawning biomass per recruit $q_0$, and steepness $h$. Steepness is defined as the proportion of virgin recruitment expected when $S$ is 20% of the virgin level (where $0.2 < h < 1$).

Spawning biomass (aggregate fecundity) $S$ is expressed

$$S_y = \sum_{a} p_a E_a N_{a,y,t} \tag{9}$$

where $p$ is the proportion of each age class that is sexually mature and $E_a$ is the average fecundity of mature individuals during the month $t$ when spawning takes place. Similarly, the equilibrium spawning biomass per recruit for a given vector of fishing mortality rates at age ($F$) is computed

$$\theta_F = \sum_{a=\alpha}^{A-1} p_a E_a\, e^{-(Z_a \tau + \sum_{j=\alpha}^{a-1} Z_j)} + \frac{p_A E_A}{1-e^{-Z_A}}\, e^{-(Z_A \tau + \sum_{j=\alpha}^{A-1} Z_j)} \tag{10}$$

where $Z_a = M_a + F_a$, $t$ is the fraction of the year elapsed at the time of spawning (= $t$/12). The virgin level ($q_0$), which is used in equation (8) above, is obtained by setting $F_a = 0$.

The age structure of the population at the start of the first year in the analysis ($y$=1) is assumed to be a virgin (unfished) condition. In that case the expected spawning biomass per recruit is computed by Eq. 10. Rearranging the spawner-recruit relationship then gives a value for the corresponding equilibrium recruitment.

$$R_\phi = R_0 \frac{4h\theta_\phi - (1-h)\theta_0}{\theta_\phi(5h-1)}. \tag{11}$$

The monthly catch of the $i$'th fishing entity (fleet) is computed as though it occurred as a pulse at the end of the month, after natural mortality and after the catch of fleets 1 through $i$-1:

$$C_{a,y,m,i} = F_{a,y,i}\left(N_{a,y,m}e^{-M_a\delta} - \sum_{k=1}^{i-1} C_{a,y,m,k}\right)\frac{\delta}{\tau_i} \tag{12}$$

where $ti$ is the duration of the fishing season in years. The corresponding catch in weight is computed by multiplying the result of Eq. 12 by the average weight at age $w_{a,y}$. Note that this formulation is only approximate when the fleets actually fish simultaneously rather than sequentially, but with monthly time steps the error is negligible.

The fishing mortality rate $F$ is separated into components representing the age-specific relative vulnerability $v$, annual effort expended $f$, and a catchability coefficient $q$:

$$F_{a,y,i} = q_{y,i} f_{y,i} v_{a,i} \tag{13}$$

The catchability coefficient $q$ is the fraction of the most vulnerable age class that is taken per unit effort. Note that $q$ may be allowed to vary from year to year rather than remain fixed in order to accommodate variations in the efficiency of the fishing process (see discussion of process errors below). The relative vulnerability coefficients $v$ implicitly include factors such as gear selectivity, size limit regulations, and the fraction of the stock exposed to the fishery. They can be modeled by a logistic selection curve (other options include gamma and double logistic):

$$v_{a,i} = \frac{1}{1 + e^{-(a - a_{50,i})/d_i}}$$

(14)

where $a_{50,i}$ is the age of 50% relative vulnerability for fleet $i$ and $d_i$ is the dispersion coefficient controlling the slope of the curve at $a_{50,i}$ (values of 0.2 or less effectively imply knife-edge selection).

Time series of catch per unit effort (CPUE) or fishery-independent abundance surveys are modeled as though the observations were made just before the catch of the fleet with the corresponding index $i$:

$$I_{y,m,i} = q_{y,i} \sum_a v_{a,i} \left( N_{a,y,m} e^{-M_{a,y}\delta} - \sum_{k=1}^{i-1} C_{a,y,m,k} \right) \frac{\delta}{\tau_i} \tag{15}$$

As for catch, the corresponding CPUE in weight is computed by multiplying (15) by $w_{a,y}$. Average weight is computed as a power function of length, which in turn is computed as a von Bertalanffy function of age:

$$w_{ay} = \gamma \left[ L_\infty (1 - e^{-k(a-t_0)}) \right]^\beta \tag{16}$$

The average weight for the plus-group depends on the age composition of the plus-group. However, to the extent that growth after the plus-age is approximately linear, the average weight may be calculated from the average age of the plus-group. Initially, it is assumed that the age composition of the plus-group is in equilibrium consistent with equation (10), in which case the average age of the plus-group at the beginning of the first year is

$$\bar{a}_{A,1} = A + \frac{e^{-(M_A+\phi_A)}}{(1 - e^{-(M_A+\phi_A)})} \tag{17}$$

Subsequently, the age of the plus-group is updated as

$$\bar{a}_{A,y+1} = \frac{AN_{A-1,y,13} + \left(\bar{a}_{A,y} + 1\right) N_{A,y,13}}{N_{A,y+1,1}} \tag{18}$$

### *3.2.1.4. Model Configuration*

Several SSASPM model configurations were presented for consideration by the SEDAR-9-AW working group. These models are described in detail in SEDAR-9-AW-04. The working group chose a single base model. The following is a description of the configuration of the SSASPM base model.

Catch and CPUE observations were assumed to be unbiased, but imprecise. The annual catches from each fleet were assumed to be equally uncertain with constant coefficient of variation, *CV*, estimated by the model. The annual CPUE values for each fleet were assumed to be less certain than the catches, and were assigned coefficients of variation twice as large as the values estimated for the catch (i.e., 2*CV*). The fleet-specific CPUE series were equally weighted.
Effort and recruitment process errors were estimated independently. Recruitment was allowed to vary inter-annually as an essentially free parameter by allowing a coefficient of variation equal to 0.4 without autocorrelation. The annual effort of the directed fleets (COM-E, COM-W and REC) were allowed to vary with a moderate variance (CV=0.5) and correlation ($r$ = 0.5). The annual effort of the Shrimp-Bycatch fleet was allowed to vary with small deviations (CV=0.2) and correlation ($r$ = 0.5). The catchability coefficients, $q$, were estimated as time-independent constants.

#### *3.2.1.5. Parameters Estimated*

Since SSASPM is an age-structured model, tens to hundreds of parameters are estimated, making it impractical to discuss them all. The parameter input file for the SSASPM base model is included as Table. 3.2.1.4.1. For each estimated parameter, this table contains the initial estimates and parameter constraints (or priors).

#### *3.2.1.6. Uncertainty and Measures of Precision*

Like the P-T production model, SSASPM accommodates parameter uncertainty by estimating process and observation errors. A complete description of the equations used to estimate process error can be found in Table 3.2.1.5.1.

#### *3.2.1.7. Benchmark / Reference points methods*

Reference points and benchmarks were calculated with regard to maximum sustainable yield (MSY) and spawning potential ratio (SPR30%).

#### *3.2.1.8. Projection methods*

Projections were run to 2016 using the projection software PRO-2BOX (Porch, 2002b). Two types of base projections were run. The first, at 74.5% of Current Yield (0.745 * geometric mean yield from 2002 to 2004) beginning in 2006. For 2005, the geometric mean yield from 2002 to 2004 was applied without reduction. This projection was intended to account for the expected 25.5% reduction in shrimp trawl bycatch after 2005. The reduction was applied to all the directed fisheries because it is not possible to apply a fleet-specific F-multiplier in SSASPM. The second base projection applies current F ($F_{2004}$) to 2005-2016

To estimate the variance of the projection, 500 bootstraps were run off the deterministic results of SSASPM. This method does not take into account the inherent variability in the parameter estimated. Instead, the bootstrap variable was simply the recruitment deviations.

### 3.2.2. SSASPM Results

#### *3.2.2.1. Measures of Overall Model Fit*

The likelihood statistics of the SSASPM base model are as follows:

| | |
|---|---|
| AIC | 1.01e+03 |
| data points | 213 |
| estimated parameters | 138 |
| AICc (small sample) | 1.53e+03 |
| Objective Function: | 3.67e+02 |

Fits the catch series of the directed fleets are shown in Figure 3.2.2.1.1 and Table 3.2.2.1.1. Note that the period from 1950-1980 is presumed to be “prehistoric”, and is used only as a “burn-in” period to scale the estimates during historic period 1981-2004. In general, fits the catch series are quite good. The shrimp bycatch fits are the most variable. The model cannot properly accommodate a constant annual shrimp bycatch estimate, nor should this assumption be regarded as biologically realistic.

Fits to the indices of abundance are summarized in Figure 3.2.2.1.2 and Table 3.2.2.1.2. The fits to the CMHL-EAST and HB-WEST indices are similar to the observed trends, but the model fits to the HB-EAST and MRFSS-EAST indices are quite flat compared to the observed values. The recent (2000-2004) increasing trend of the CMHL-WEST index is not fit by the Set 1 SSASPM model runs.

The fits to the observed age composition are summarized in Figures 3.2.2.1.3 to 3.2.2.1.5. In general, the estimated age composition closely resembles the observations from otolith samples.

#### *3.2.2.2. Parameter estimates*

Selected parameter estimates, including $B_0$, $B_{2004}$, $F_{2004}$, the Beverton and Holt recruitment parameters, recruitment deviation estimates, and the biomass trajectory are summarized in Table. 3.2.2.2.1. Estimates of standard deviation are also tabulated.

The selectivity parameters for the directed fisheries were estimated using a logistic equation. The results are illustrated in Figure 3.2.2.2.1. Selectivity for the directed fleets is near 0 for Age 1 animals. For the eastern commercial fishery, a50 occurs at approximately age 2, while in the other sectors (commercial west and recreational), a50 is about age 3. For all directed fleets, all individuals age 5+ are fully vulnerable to fishing.

#### *3.2.2.3. Stock Biomass and Recruitment*

Annual trends in spawning stock biomass (SSB) and SSB relative to virgin ($SSB/S_{1950}$), MSY and SPR30% levels are summarized in Figure 3.2.2.3.1. All annual biomass estimates are summarized in Table 3.2.2.3.1. Estimates prior to 1981 are considered “prehistoric”, and are used as a burn in to scale the model results. SSB statistics varied without obvious trend during 1981-1990, but generally declined thereafter. However, according the base run SSASPM results, the population is never below $SSB_{MSY}$ and $SSB_{SPR30\%}$. In 2004, SSB was 44% of $SSB_{1950}$, $SSB/SSB_{MSY}$ was 1.8 and $SSB/SSB_{SPR30\%}$ was 1.75, indicating a population that is not currently overfished.

#### *3.2.2.4. Fishing Mortality*

Annual trends in fishing mortality (F), and F relative to MSY and SPR30% levels are summarized in Figure 3.2.2.4.1 and Table 3.2.2.4.1. In 1950, F was assumed to be negligible. The linear increase during the “prehistoric” period (1950-1981) is dictated by the model structure (SSASPM-linear). F statistics varied without obvious trend during 1981-2000, but a general increase in F is notable during 2001-2004.

According to the SSASPM base run, F is less than $F_{MSY}$ and $F_{SPR30\%}$ throughout the time series. In 2004, $F/F_{MSY}$ was 0.65 and, $F/F_{SPR30\%}$ was 0.67, indicating a population that is not currently undergoing overfishing.

#### *3.2.2.5. Recruitment*

Annual estimates of recruitment (Age 1) are summarized in Figure 3.2.2.5.1 and Table 3.2.2.5.1. “Prehistoric” (1950-1980) recruitment estimates are considered as a burn in to scale the SSASPM model results. During the “historical” period (1981-2004), recruitment varies without obvious trend. However, it is important to note that the average recruitment during 2002-2004 (geometric mean = 1.0E+07) is substantially lower than the average during the period 1981-2004 (geometric mean = 1.7E+07).

The predicted spawner-recruit relationship and the estimated values during the “historic” period (1981-2004) are shown in Figure 3.2.2.5.2. There appears to be little relationship between the spawning stock biomass and recruitment at age 1.

#### *3.2.2.6. Measures of Parameter Uncertainty*

Parameter uncertainty was addressed by estimating process and observation errors. The standard deviations of the estimated parameters are summarized in the previously cited Table 3.2.2.2.1.

#### *3.2.2.7. Retrospective and Sensitivity Analyses*

No retrospective analyses were preformed. However, several sensitivity analyses were presented to the SEDAR9-AW working group. Models were presented that estimated steepness, fixed steepness at 0.60 (the mean value suggested by the data workshop), used larger effort deviation for the shrimp bycatch fleet (50%CV), and allowed or did not allow recruitment deviations. These sensitivity runs were not preferred by the AW working group, and were subsequently not pursued. They are described in detail in document SEDAR9-AW-04.

### *3.2.2.8. Benchmarks / Reference Points*

The benchmarks and reference points estimated for the SSASPM base run are summarized in Table 3.2.2.8.1. Unlike the P-T production model, the SSASPM base model suggests that vermilion snapper are not overfished ($SSB_{2004}/SSB_{MSY}$ = 1.80; ($SSB_{2004}/SSB_{SPR30\%}$ = 1.76), nor was overfishing occurring ($F_{2004}/F_{MSY}$ = 0.65; ($F_{2004}/F_{SPR30\%}$ = 0.67) as of 2004.

### *3.2.2.9. Projections*

#### *Base Projections*

Figure 3.2.2.9.1.1 and Table 3.2.2.9.1.1 summarize the “Current Yield” projection results. Recall that this projection employs a 25.5% reduction in yield beginning in 2006. Using this projection scenario, yield is, by definition, constant at 4.35 million pounds during 2006-2016, and this yield is sustainable. The spawning stock biomass increases during the “Current Yield” projection, implying that fishing at “Current Yield”, which is below MSY (5.5 million pounds) will allow the population status to improve. The projected recruitment estimates appear to be lower than the mean of the observed recruitments (1986-2004).

Figure 3.2.2.9.1.2 and Table 3.2.2.9.1.2 summarize the “Current F” projection results. Using this projection scenario, yield gradually decreases to about 5.2 million pounds in 2016. This value is slightly below MSY. The spawning stock biomass decreases slowly throughout the projection interval, although it remains above $SSB_{MSY}$ and $SSB_{SPR30\%}$. The projected recruitment estimates appear to be lower than the mean of the observed recruitments (1986-2004).

#### *Additional Projections (Sensitivity Analysis)*

Because the recruitment estimates from the base projections are lower than the mean of the observed recruitment series (1986-2004), the AW working group requested an additional set of projections to examine the sensitivity of the results to higher recruitment estimated.

For these projections, the recruitment parameters were re-estimated using only the recent data (1986-2004), and these parameters were entered into the projection. This procedure required the use of a fixed steepness. The working group selected a steepness value of 0.8, which was close to the value estimated for the SSASPM base run.

Figure 3.2.2.9.2.1 and Table 3.2.2.9.2.1 summarize the “Current Yield” projection results for the sensitivity case. Recall that this projection employs a 25.5% reduction in yield beginning in 2006. Using this projection scenario, yield is, by definition, constant at 4.35 million pounds during 2006-2016, and this yield is sustainable. The spawning stock biomass increases during the "Current Yield" projection, implying that fishing at "Current Yield", which is below MSY (5.5 million pounds) will allow the population status to improve. The projected recruitment estimates are close to the mean of the observed recruitments (1986-2004), as expected.

Figure 3.2.2.9.2.2 and Table 3.2.2.9.2.2 summarize the "Current F" projection results for the sensitivity case. Using this projection scenario, yield remains steady at about 6.5 million pounds throughout the time series. This value is slightly below MSY. The spawning stock biomass also remains virtually unchanged throughout the projection interval. SSB is above $SSB_{MSY}$ and $SSB_{SPR30\%}$ through 2016. The projected recruitment estimates are close to the mean of the observed recruitments (1986-2004), as expected.

# 4. Panel Recommendations and Comment

## 4.1. Critique and review of models considered

### 4.1.1. Pella-Tomlinson production model (PT)

The Pella-Tomlinson production model with the shape parameter held constant at 2.0 is a logistic or Schaefer production model that uses landings and effort or catch per unit effort to estimate the rate of growth of the population, r, and a population carrying capacity, K. Since the curve of landings on effort is dome shaped, there is a maximum level and if we assume that the curve represents sustainable conditions then that value becomes the maximum sustainable yield (MSY).

The PT model is very straight forward and this implementation (Porch, 2001) allows uncertainty in the input data. The lack of biological flexibility in the model prevents the model from comparing maturity with selectivity or having higher steepness in the stock-recruit curve, i.e., this model cannot capture resiliency. The model was used to provide continuity with the earlier in 2001. The model preformed well as a continuity run with similar r values (0.64 in the 2001 assessment and 0.67 in this assessment), K values (21.2 million lb in 2001 assessment and 21.5 million lb in this assessment, and MSY values (3.4 million lb in 2001 assessment and 3.6 million lb in this assessment (Table 3.1.2.7.1). The fishing mortality ratio in 2004 was 2.70 and the biomass ratio was 0.40 indicating that the stock is overfished and undergoing overfishing.

### 4.1.2. State-space age-structured production model (SSASPM)

The majority of the Stock Assessment Workshop participants thought that a model that incorporated age specific population dynamics (i.e. fecundity, maturity, size-at-age, selectivity), would be more informative about stock status. In the case of vermilion snapper, all of the age data is from recent years (1994-2004, with most from 2000-2004) but the participants felt the data were sufficient to develop selectivity curves for the commercial and recreational fisheries. Selectivity is important because vermilion snapper likely mature before becoming fully vulnerable to fishing pressure (Figure 3.2.2.2.1) which increases their resiliency. The SSASPM model also allows autocorrelated effort estimates and CVs on the input data. Unlike the P-T production model, the SSASPM .base run indicates that during the period 1981-2004, GOM vermilion snapper have never been overfished, not has overfishing occurred. In every year, $SSB/SSB_{MSY}$ has exceeded 1.80 and $F/F_{MSY}$ is less than or equal to 0.7. . In 2004, the benchmarks statistics were $SSB/SSB_{MSY}$ = 1.80, $SSB/SSB_{SPR30\%}$ = 1.75, $F/F_{MSY}$ = 0.65 and $F/F_{SPR30\%}$ = 0.67. Although the SSAPSM base model indicates that the status of the stock is healthy, it is important to note the spawning stock biomass has generally decreased throughout the time series (Figure 3.2.2.3.1) while fishing mortality has increased (Figure 3.2.2.4.1).

## 4.2. Preferred model and configuration recommendations

The AW participants preferred the SSASPM model on the basis of its considering more of the age-structured biology and fishery characteristics of vermilion snapper. At the time of the recommendation (AW1, August 2005, Miami FL), we did not know what the model would estimate for the stock condition. SSASPM base and sensitivity runs were presented and discussed in detail at the second assessment workshop (AW2, December 2005, Atlanta GA). The AW panel did not recommend any further revisions to the base run configuration. In other species, the stock condition changes depending upon whether the model is allowed to estimate steepness or whether steepness is fixed but in vermilion snapper the model solved for the same 0.8 value that the assessment workshop recommended so the stock-recruit relationship was not an issue.

## 4.3. Status of stock declarations

Based on the SSASPM model, the stock was not overfished ($F/F_{MSY}$ = 0.65 and $F/F_{SPR30\%}$ = 0.67) nor undergoing overfishing ($SSB/SSB_{MSY}$ = 1.80, $SSB/SSB_{SPR30\%}$ = 1.75) at the end of 2004; however, the increasing fishing mortality rates and the associated decreasing spawning biomass indicates that the stock could become overfished if fishing mortality continues to increase.

It is estimated that shrimp effort has decreased recently (equivalent to a 25.5% reduction applied fleet-wide). If this is so, the status of vermilion snapper would benefit, as the fishing mortality on ages 0 and 1 would decline, and some of these animals would survive to maturity, and enter the directed fisheries at later ages.

## 4.4. Management evaluation

As established by Amendment 23 to the Reef Fish FMP implemented in May 2005, MSY for vermilion snapper is the yield associated with $F_{MSY}$ when the stock is at equilibrium. MSY was estimated to be 3.37 mp based on the last stock assessment (range 3.18 to 4.03 mp) (Porch and Cass-Calay, 2001). OY is the yield corresponding to a fishing mortality rate ($F_{OY}$) defined as $0.75*F_{MSY}$ (or $F_{MSY}$ proxy) when the stock is at equilibrium. The last stock assessment estimated $F_{MSY}$ as 0.32 (RFSAP, 2001). Maximum Fishing Mortality Threshold (MFMT) is set equal to $F_{MSY}$. Minimum Stock Size Threshold (MSST) is set equal to $(1-M)*B_{MSY}$ (or $B_{MSY}$ proxy). The last stock assessment estimated $B_{MSY}$ as 10.6 mp (Porch and Cass-Calay, 2001). Based on this information, MSST would equal 7.95 mp.

The rebuilding plan for vermilion snapper specified that the stock be rebuilt in ten years using a stepped strategy that holds harvest constant for an initial four year interval consistent with the average of the same four years under a constant fishing mortality rate, then three-year intervals thereafter. The allowable harvest starting in 2004 was 1.475 mp and equated to a 25.5

percent reduction in directed harvest based on 2003 estimated landings. In 2008 allowable harvest would increase to 2.058 mp and in 2011 harvest would increase to 2.641 mp.

The current minimum size for recreationally and commercially caught vermilion snapper is 11 inches TL; the recreational bag limit is 10 fish within the 20-reef fish aggregate bag limit; and a commercial closed season was established from April 22 through May 31.

The current rebuilding plan was developed using the 2001 P-T production model. The SSASPM model provides very different results. According to the base model chosen by the SEDAR9-AW2 panel, the Gulf of Mexico stock of vermilion snapper has never been overfished, and has never undergone overfishing. Thus, it is not possible to evaluate the progress of the rebuilding plan, except to state that the stock exceeded $B/B_{MSY}$ in 2004, and is projected to continue to exceed $B/B_{MSY}$ throughout the ten-year rebuilding plan. $B_{2014}/B_{MSY} > 1.5$, even when current (2004) F is projected. Current yield projections are more optimistic.

## 4.5. Model Comparison

The results of the P-T production model and the SSASPM model are contrasted on a control rules plot in Figure 4.6.1. It is clear the models have very different outcomes. This is due to a variety of reasons:

1. The model is implemented with data from 1981-2004 with the assumption that the stock was at virgin conditions in 1950.
2. The model was implemented with an assumption of a constant annual catch of 6.9 million fish for the shrimp bycatch. The previous assessment used an annually varying shrimp bycatch series that was not supported by the data workshop panel.
3. SSASPM is an age-structured model which utilized maturity, fecundity, selectivity functions, size-at-age information and age composition. The previous assessment (P-T production model) was not age-structured and did not use age composition information.

SSASPM results appear to differ from the production model primarily due to the assumption of virgin condition in 1950. This assumption scales the 1950-1980 catches to low levels. This version of SSASM fits a linear increase from the virgin condition (zero catch) in 1950 to the first year of observed data (1981). The P-T production model results suggest the population was already overfished in 1986, implying high catches in the 1980s. This implication does not appear to be realistic given the reported catch series (Table 3.1.1.2.1)

The level of assumed shrimp bycatch also impacts the status of vermilion snapper (SEDAR9-AW-04). Lower levels of shrimp bycatch cause lower estimates of productivity (steepness), and consequently poorer status. Therefore, the stock status of vermilion snapper is predicted to be less optimistic if the assumed shrimp bycatch is overestimated.

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# 6. Tables

**Table 3.2.2.8.1.** Management and biomass status benchmarks for the SSASPM base case and sensitivity analysis.

**Table 3.2.2.9.1.1.** Results of the "Current Yield" projection of the SSASPM base model.

**Table 3.2.2.9.1.2.** Results of the "Current F" projection of the SSASPM base model.

**Table 3.2.2.9.2.1** Results of the "Current Yield" projection of the SSASPM sensitivity case. This projection uses recruitment parameters estimating using only recent data (1986-2004).

**Table 3.2.2.9.2.2** Results of the "Current F" projection of the SSASPM sensitivity case. This projection uses recruitment parameters estimating using only recent data (1986-2004).

**Table 3.1.1.2.1.** Catch and effort series used for the continuity case.

| | CATCH SERIES (1000s of POUNDS) | | | EFFORT (DAYS FISHED) |
|---|---|---|---|---|
| YEAR | COMMERCIAL | REC (HB+MRFSS+TPWD) | SHRIMP BYCATCH | SHRIMP FLEET |
| 1986 | 1749.40 | 535.21 | 534.15 | 226798 |
| 1987 | 1605.40 | 601.70 | 534.15 | 241902 |
| 1988 | 1554.50 | 658.24 | 534.15 | 205812 |
| 1989 | 1658.80 | 423.70 | 534.15 | 221165 |
| 1990 | 2454.90 | 657.98 | 534.15 | 211860 |
| 1991 | 1795.00 | 695.63 | 534.15 | 223388 |
| 1992 | 2267.90 | 860.14 | 534.15 | 216669 |
| 1993 | 2719.50 | 740.50 | 534.15 | 204482 |
| 1994 | 2639.20 | 684.71 | 534.15 | 195742 |
| 1995 | 2178.00 | 750.47 | 534.15 | 176589 |
| 1996 | 1827.30 | 378.74 | 534.15 | 189653 |
| 1997 | 2125.80 | 440.98 | 534.15 | 207912 |
| 1998 | 1732.60 | 293.53 | 534.15 | 216999 |
| 1999 | 1982.30 | 391.78 | 534.15 | 200475 |
| 2000 | 1459.90 | 283.16 | 534.15 | 192073 |
| 2001 | 1715.10 | 551.01 | 534.15 | 197644 |
| 2002 | 2008.60 | 443.24 | 534.15 | 194186 |
| 2003 | 2415.70 | 557.42 | 534.15 | 168153 |
| 2004 | 2134.40 | 741.75 | 534.15 | 188014 |

**Table 3.1.1.2.2.** Indices of abundance used for the continuity case.

| YEAR | Commercial HL | Headboat East |
|---|---|---|
| 1986 | | 1.0320 |
| 1987 | | 0.9415 |
| 1988 | | 2.0546 |
| 1989 | | 1.0626 |
| 1990 | | 1.6947 |
| 1991 | | 1.9385 |
| 1992 | | 2.2609 |
| 1993 | 1.2189 | 1.4096 |
| 1994 | 1.3143 | 1.1549 |
| 1995 | 1.0144 | 1.1296 |
| 1996 | 0.9378 | 0.6480 |
| 1997 | 1.0093 | 0.6969 |
| 1998 | 0.9449 | 0.2477 |
| 1999 | 0.8986 | 0.4683 |
| 2000 | 0.6895 | 0.3688 |
| 2001 | 0.8347 | 0.3638 |
| 2002 | 0.9428 | 0.5412 |
| 2003 | 1.0679 | 0.4629 |
| 2004 | 1.1269 | 0.5237 |

**Table 3.1.1.3.1.** Stochastic equations used to define the state space Pella-Tomlinson model.

| Variables | Description |
|---|---|
| *Process functions for state variables* | |
| $m_t = m_0 e^{-\varepsilon_{m,t}},\ \varepsilon_{m,t} = \rho_m \varepsilon_{m,t-1} + a_{m,t}$ | exponent controlling inflection point of production curve |
| $r_t = r_0 e^{-\varepsilon_{r,t}},\ \varepsilon_{r,t} = \rho_r \varepsilon_{r,t-1} + a_{r,t}$ | intrinsic rate of production |
| $k_t = \frac{B_1}{\alpha} e^{-\varepsilon_{k,t}},\ \varepsilon_{k,t} = \rho_k \varepsilon_{k,t-1} + a_{k,t}$ | carrying capacity of environment |
| $q_{f,t} = q_{f,0} e^{-\varepsilon_{q,f,t}},\ \varepsilon_{q,f,t} = \rho_{q,f} \varepsilon_{q,f,t-1} + a_{q,f,t}$ | catchability for fishery f |
| $E_{f,t} = E_{f,0} e^{-\varepsilon_{E,f,t}},\ \varepsilon_{E,f,t} = \rho_{E,f} \varepsilon_{E,f,t-1} + a_{E,f,t}$ | effort expended by fishery f |
| *Observation functions for data variables* | |
| $C_{ft} = \left( \delta q_{ft} E_{ft} \sum_{j=1}^{16} B_{t+j\delta} \right) e^{-\varepsilon_{C,f,t}},\ \varepsilon_{C,f,t} = \rho_{C,f} \varepsilon_{C,f,t-1} + a_{C,f,t}$ | catch of fishery *f* |
| $I_{ft} = \left( \delta q_{ft} \sum_{j=1}^{16} B_{t+j\delta} \right) e^{-\varepsilon_{I,f,t}},\ \varepsilon_{I,f,t} = \rho_{I,f} \varepsilon_{I,f,t-1} + a_{I,f,t}$ | CPUE of fishery *f* |
| *State moments* | |
| $B_{t+\delta} = \frac{B_t(1 + r_t\delta)}{1 + (r_t(B_t / k_t)^{m_t - 1} + F_t)\delta}$ | biomass |
| $F_t = \sum_{f=1}^{n} q_{ft} E_{ft}$ | fishing mortality rate |

**Table 3.1.1.4.1 .** Parameter configuration file for the continuity case.

```
# INPUT FILE FOR PROGRAM PT-MODEL
# CLASS
#  |        SET (corresponds to pointers in data series.
#  |         |     NATURE specifies deterministic and stochastic parts of parameter class)
#  |         |     |        METHOD OF ESTIMATION (either 'FIXED' or 'ESTIMATED')
#  |         |     |        |               PHASE (immaterial if method = 'FIXED')
#  |         |     |        |                |    BEST ESTIMATE
#  |         |     |        |                |    |             LOWER BOUND
#  |         |     |        |                |    |             |             UPPER BOUND
#  |         |     |        |                |    |             |             |      (-)CV or (+)VARIANCE OF PRIOR
#  |         |     |        |                |    |             |             |             |         PDF OF PRIOR
#  |         |     |        |                |    |             |             |             |            |
 'M'        1    'CONST'  'FIXED'          4    0.2000E+01    0.1000E+00    0.9000E+01    0.2231E+00  'FREQUENTIST'
 'M'        1    'RHO'    'FIXED'          4    0.0000E+00    0.0000E+00    0.1000E+13    0.1000E+01  'FREQUENTIST'
 'M'        1    'VAR'    'FIXED'          3    0.0000E+00    0.0000E+00    0.1000E+13    0.1000E+01  'FREQUENTIST'
#
 'R'        1    'CONST'  'ESTIMATED'      3    0.6400E+00    0.1000E+00    1.0000E+00    0.5000E+01  'FREQUENTIST'
 'R'        1    'RHO'    'FIXED'          4    0.0000E+00    0.0000E+00    0.1000E+13    0.1000E+01  'FREQUENTIST'
 'R'        1    'VAR'    'FIXED'          3    0.0000E+00    0.0000E+00    0.1000E+13    0.1000E+01  'FREQUENTIST'
#
 'K'        1    'CONST'  'ESTIMATED'      2    0.5000E+00    0.1000E+00    0.1000E+01    0.5000E+01  'FREQUENTIST'
 'K'        1    'RHO'    'FIXED'          4    0.0000E+00    0.0000E+00    0.1000E+13    0.1000E+01  'FREQUENTIST'
 'K'        1    'VAR'    'FIXED'          3    0.0000E+00    0.0000E+00    0.1000E+13    0.1000E+01  'FREQUENTIST'
#
 'Q'        1    'CONST'  'ESTIMATED'      1    0.1000E+00    0.0000E+00    0.1000E+01    0.5000E+01  'FREQUENTIST'
 'Q'        1    'RHO'    'FIXED'          5    0.0000E+00    0.0000E+00    0.1000E+01    0.1000E+01  'FREQUENTIST'
 'Q'        1    'VAR'    'FIXED'          4    0.0000E+00    0.0000E+00    0.1000E+21    0.1000E+01  'FREQUENTIST'
 'Q'        2    'CONST'  'ESTIMATED'      1    0.1000E+00    0.0000E+00    0.1000E+01    0.5000E+01  'FREQUENTIST'
 'Q'        2    'RHO'    'FIXED'          5    0.0000E+00    0.0000E+00    0.1000E+01    0.1000E+01  'FREQUENTIST'
 'Q'        2    'VAR'    'FIXED'          4    0.0000E+00    0.0000E+00    0.1000E+21    0.1000E+01  'FREQUENTIST'
 'Q'        3    'CONST'  'ESTIMATED'      1    0.1000E+00    0.0000E+00    0.1000E+01    0.5000E+01  'FREQUENTIST'
 'Q'        3    'RHO'    'FIXED'          5    0.0000E+00    0.0000E+00    0.1000E+01    0.1000E+01  'FREQUENTIST'
 'Q'        3    'VAR'    'FIXED'          4    0.0000E+00    0.0000E+00    0.1000E+21    0.1000E+01  'FREQUENTIST'
#
 'E'        1    'CONST'  'ESTIMATED'      1    0.2400E+04    0.1000E+03    0.1000E+07    0.5000E+01  'FREQUENTIST'
 'E'        1    'RHO'    'FIXED'          5    0.5000E+00    0.0000E+00    0.9900E+00    0.1000E+01  'FREQUENTIST'
 'E'        1    'VAR'    'FIXED'          4    0.2231E+00    0.0000E+00    0.1000E+22    0.1000E+01  'FREQUENTIST'
 'E'        1    'DEVS1'  'ESTIMATED'      2    0.0000E+00   -0.5000E+01    0.5000E+01    0.1000E+00  'LOGNORMAL'
 'E'        2    'CONST'  'ESTIMATED'      1    0.5186E+03    0.1000E+02    0.1000E+07    0.5000E+01  'FREQUENTIST'
 'E'        2    'RHO'    'FIXED'          5    0.5000E+00    0.0000E+00    0.9900E+00    0.1000E+01  'FREQUENTIST'
 'E'        2    'VAR'    'FIXED'          4    0.2231E+00    0.0000E+00    0.1000E+22    0.1000E+01  'FREQUENTIST'
 'E'        2    'DEVS1'  'ESTIMATED'      2    0.0000E+00   -0.5000E+01    0.5000E+01    0.1000E+01  'LOGNORMAL'
 'E'        3    'CONST'  'FIXED'          1    0.1000E+01    0.1000E+00    0.1000E+03    0.1000E+01  'FREQUENTIST'
 'E'        3    'RHO'    'FIXED'          5    0.5000E+00    0.0000E+00    0.9900E+00    0.1000E+01  'FREQUENTIST'
 'E'        3    'VAR'    'FIXED'          4    0.2231E+00    0.0000E+00    0.1000E+22    0.1000E+01  'FREQUENTIST'
 'E'        3    'DEVS'   'ESTIMATED'      2    0.0000E+00   -0.5000E+01    0.5000E+01    0.1000E+01  'LOGNORMAL'
#
 'C_D'      1    'VAR'    'FIXED'          4    0.1000E+01    0.1000E+00    0.5000E+01    0.1000E+01  'FREQUENTIST'
 'I_D'      1    'VAR'    'FIXED'          5    0.1028E+00    0.1000E-01    0.1000E+01    0.1000E+01  'FREQUENTIST'
 'E_D'      1    'VAR'    'FIXED'          4    0.1000E+01    0.1000E-03    0.1000E+01    0.1000E+01  'FREQUENTIST'
 'V'        1    'CONST'  'FIXED'          6    0.1000E+01    0.1000E-02    0.1000E+02    0.1000E+01  'FREQUENTIST'
```

**Table 3.1.2.1.1.** Fits to the catch series (millions of pounds) used for the continuity case.

| | COMMERCIAL | | | RECREATIONAL | | | SHRIMP BYCATCH | | |
|---|---|---|---|---|---|---|---|---|---|
| YEAR | OBS | PRED | % DIFF | OBS | PRED | % DIFF | OBS | PRED | % DIFF |
| 1986 | 1.749 | 2.034 | 16.27% | 0.535 | 0.638 | 19.21% | 0.534 | 0.534 | -0.06% |
| 1987 | 1.605 | 1.673 | 4.21% | 0.602 | 0.594 | -1.23% | 0.534 | 0.577 | 7.93% |
| 1988 | 1.554 | 1.645 | 5.83% | 0.658 | 0.637 | -3.29% | 0.534 | 0.637 | 19.27% |
| 1989 | 1.659 | 1.756 | 5.88% | 0.424 | 0.439 | 3.66% | 0.534 | 0.720 | 34.88% |
| 1990 | 2.455 | 2.464 | 0.39% | 0.658 | 0.652 | -0.92% | 0.534 | 0.757 | 41.71% |
| 1991 | 1.795 | 1.963 | 9.36% | 0.696 | 0.712 | 2.39% | 0.534 | 0.802 | 50.07% |
| 1992 | 2.268 | 2.490 | 9.80% | 0.860 | 0.881 | 2.39% | 0.534 | 0.815 | 52.62% |
| 1993 | 2.720 | 3.190 | 17.28% | 0.740 | 0.769 | 3.84% | 0.534 | 0.741 | 38.76% |
| 1994 | 2.639 | 3.183 | 20.62% | 0.685 | 0.689 | 0.66% | 0.534 | 0.606 | 13.41% |
| 1995 | 2.178 | 2.536 | 16.46% | 0.750 | 0.707 | -5.81% | 0.534 | 0.492 | -7.91% |
| 1996 | 1.827 | 1.940 | 6.17% | 0.379 | 0.366 | -3.36% | 0.534 | 0.445 | -16.71% |
| 1997 | 2.126 | 2.199 | 3.44% | 0.441 | 0.415 | -5.91% | 0.534 | 0.415 | -22.29% |
| 1998 | 1.733 | 1.857 | 7.16% | 0.294 | 0.293 | -0.21% | 0.534 | 0.378 | -29.16% |
| 1999 | 1.982 | 1.938 | -2.24% | 0.392 | 0.375 | -4.19% | 0.534 | 0.348 | -34.80% |
| 2000 | 1.460 | 1.537 | 5.26% | 0.283 | 0.295 | 4.17% | 0.534 | 0.335 | -37.28% |
| 2001 | 1.715 | 1.740 | 1.44% | 0.551 | 0.523 | -5.08% | 0.534 | 0.345 | -35.36% |
| 2002 | 2.009 | 2.083 | 3.68% | 0.443 | 0.447 | 0.82% | 0.534 | 0.338 | -36.80% |
| 2003 | 2.416 | 2.405 | -0.43% | 0.557 | 0.557 | -0.09% | 0.534 | 0.310 | -41.89% |
| 2004 | 2.134 | 2.276 | 6.62% | 0.742 | 0.723 | -2.47% | 0.534 | 0.276 | -48.39% |

**Table 3.1.2.1.2.** Fit to the relative effort series used for the continuity case.

| | RELATIVE EFFORT (SHRIMP FLEET) | | |
|---|---|---|---|
| YEAR | OBS | PRED | % DIFF |
| 1986 | 1.111 | 0.827 | -25.55% |
| 1987 | 1.185 | 0.853 | -27.97% |
| 1988 | 1.008 | 0.884 | -12.30% |
| 1989 | 1.083 | 0.938 | -13.43% |
| 1990 | 1.038 | 0.975 | -6.07% |
| 1991 | 1.094 | 1.043 | -4.67% |
| 1992 | 1.061 | 1.099 | 3.61% |
| 1993 | 1.002 | 1.123 | 12.17% |
| 1994 | 0.959 | 1.093 | 13.96% |
| 1995 | 0.865 | 1.050 | 21.43% |
| 1996 | 0.929 | 1.023 | 10.18% |
| 1997 | 1.018 | 1.000 | -1.77% |
| 1998 | 1.063 | 0.942 | -11.33% |
| 1999 | 0.982 | 0.877 | -10.67% |
| 2000 | 0.941 | 0.816 | -13.25% |
| 2001 | 0.968 | 0.805 | -16.82% |
| 2002 | 0.951 | 0.801 | -15.78% |
| 2003 | 0.824 | 0.822 | -0.14% |
| 2004 | 0.921 | 0.942 | 2.27% |

**Table 3.1.2.1.3.** Fits to the indices used for the continuity case.

| | COMMERCIAL HANDLINE | | | HEADBOAT EAST | | |
|---|---|---|---|---|---|---|
| YEAR | OBS | PRED | % DIFF | OBS | PRED | % DIFF |
| 1986 | - | - | - | 1.032 | 1.333 | 29.20% |
| 1987 | - | - | - | 0.942 | 1.395 | 48.20% |
| 1988 | - | - | - | 2.055 | 1.488 | -27.56% |
| 1989 | - | - | - | 1.063 | 1.587 | 49.32% |
| 1990 | - | - | - | 1.695 | 1.604 | -5.36% |
| 1991 | - | - | - | 1.939 | 1.587 | -18.12% |
| 1992 | - | - | - | 2.261 | 1.531 | -32.27% |
| 1993 | 1.219 | 1.338 | 9.80% | 1.410 | 1.363 | -3.34% |
| 1994 | 1.314 | 1.125 | -14.42% | 1.155 | 1.145 | -0.85% |
| 1995 | 1.014 | 0.950 | -6.33% | 1.130 | 0.967 | -14.37% |
| 1996 | 0.938 | 0.882 | -5.96% | 0.648 | 0.898 | 38.56% |
| 1997 | 1.009 | 0.842 | -16.59% | 0.697 | 0.857 | 22.97% |
| 1998 | 0.945 | 0.815 | -13.80% | 0.248 | 0.829 | 234.78% |
| 1999 | 0.899 | 0.806 | -10.35% | 0.468 | 0.820 | 75.13% |
| 2000 | 0.689 | 0.833 | 20.81% | 0.369 | 0.848 | 129.93% |
| 2001 | 0.835 | 0.870 | 4.22% | 0.364 | 0.886 | 143.44% |
| 2002 | 0.943 | 0.855 | -9.30% | 0.541 | 0.871 | 60.84% |
| 2003 | 1.068 | 0.766 | -28.30% | 0.463 | 0.779 | 68.41% |
| 2004 | 1.127 | 0.594 | -47.30% | 0.524 | 0.605 | 15.44% |

**Table. 3.1.2.2.1.** The parameter estimates from the continuity case.

| **Parameter Estimate** | | Value | Standard Deviation |
|---|---|---|---|
| Initial biomass (lbs) | B1986 | 7.916E+06 | 2.09E+03 |
| Intrinsic rate of growth | r | 6.681E-01 | 2.61E-02 |
| Carrying Capacity (lbs) | k | 2.152E+07 | 1.41E+03 |
| | | | |
| Catchability (q) | | | |
| Commercial | q1 | 1.638E-04 | 3.43E-05 |
| Recreational | q2 | 1.667E-04 | 4.15E-05 |
| Shrimp Bycatch | q3 | 8.073E-02 | 2.38E-02 |

| Relative Effort (unitless) | | Fishery | |
|---|---|---|---|
| Year | Commercial | Recreational | Shrimp Bycatch |
| 1986 | 1.553E+03 | 4.785E+02 | 8.269E-01 |
| 1987 | 1.221E+03 | 4.259E+02 | 8.533E-01 |
| 1988 | 1.125E+03 | 4.277E+02 | 8.840E-01 |
| 1989 | 1.127E+03 | 2.768E+02 | 9.377E-01 |
| 1990 | 1.564E+03 | 4.065E+02 | 9.747E-01 |
| 1991 | 1.259E+03 | 4.487E+02 | 1.043E+00 |
| 1992 | 1.655E+03 | 5.751E+02 | 1.099E+00 |
| 1993 | 2.383E+03 | 5.644E+02 | 1.123E+00 |
| 1994 | 2.830E+03 | 6.019E+02 | 1.093E+00 |
| 1995 | 2.669E+03 | 7.308E+02 | 1.050E+00 |
| 1996 | 2.200E+03 | 4.076E+02 | 1.023E+00 |
| 1997 | 2.612E+03 | 4.841E+02 | 1.000E+00 |
| 1998 | 2.280E+03 | 3.533E+02 | 9.423E-01 |
| 1999 | 2.406E+03 | 4.577E+02 | 8.771E-01 |
| 2000 | 1.845E+03 | 3.479E+02 | 8.160E-01 |
| 2001 | 2.000E+03 | 5.905E+02 | 8.051E-01 |
| 2002 | 2.436E+03 | 5.133E+02 | 8.009E-01 |
| 2003 | 3.141E+03 | 7.145E+02 | 8.224E-01 |
| 2004 | 3.832E+03 | 1.197E+03 | 9.417E-01 |

**Table 3.1.2.3.1.** Annual population biomass (abundance) estimates for the continuity case.

| YEAR | BIOMASS (millions of lbs) | $B/B_{MSY}$ |
|---|---|---|
| 1986 | 7.916 | 0.736 |
| 1987 | 8.064 | 0.749 |
| 1988 | 8.622 | 0.801 |
| 1989 | 9.179 | 0.853 |
| 1990 | 9.795 | 0.910 |
| 1991 | 9.483 | 0.881 |
| 1992 | 9.551 | 0.888 |
| 1993 | 8.898 | 0.827 |
| 1994 | 7.614 | 0.708 |
| 1995 | 6.293 | 0.585 |
| 1996 | 5.414 | 0.503 |
| 1997 | 5.362 | 0.498 |
| 1998 | 4.960 | 0.461 |
| 1999 | 4.986 | 0.463 |
| 2000 | 4.863 | 0.452 |
| 2001 | 5.278 | 0.490 |
| 2002 | 5.341 | 0.496 |
| 2003 | 5.123 | 0.476 |
| 2004 | 4.320 | 0.401 |

**Table 3.1.2.4.1.** Annual fishing mortality estimates for the continuity case.

| YEAR | F | $F/F_{MSY}$ |
|---|---|---|
| 1986 | 0.401 | 1.200 |
| 1987 | 0.340 | 1.017 |
| 1988 | 0.327 | 0.979 |
| 1989 | 0.306 | 0.917 |
| 1990 | 0.403 | 1.205 |
| 1991 | 0.365 | 1.093 |
| 1992 | 0.456 | 1.364 |
| 1993 | 0.575 | 1.721 |
| 1994 | 0.652 | 1.952 |
| 1995 | 0.644 | 1.927 |
| 1996 | 0.511 | 1.529 |
| 1997 | 0.589 | 1.764 |
| 1998 | 0.508 | 1.522 |
| 1999 | 0.541 | 1.620 |
| 2000 | 0.426 | 1.275 |
| 2001 | 0.491 | 1.470 |
| 2002 | 0.549 | 1.644 |
| 2003 | 0.700 | 2.095 |
| 2004 | 0.903 | 2.703 |

**Table 3.1.2.7.1.** Management and biomass status benchmarks for the 2001 base case and the continuity case.

| Benchmark | 2001 Base Run | 2005 Continuity Case |
|---|---|---|
| B1986 (LBS) | 6.18E+06 | 7.92E+06 |
| B1999 (LBS) | 3.77E+06 | 4.99E+06 |
| B2004 (LBS) | - | 4.32E+06 |
| BMSY (LBS) | 1.06E+07 | 1.08E+07 |
| B1986/BMSY | 0.584 | 0.736 |
| B1999/BMSY | 0.356 | 0.463 |
| B2004/BMSY | - | 0.401 |
| | | |
| F1986 | 0.443 | 0.401 |
| F1999 | 0.632 | 0.541 |
| F2004 | - | 0.903 |
| FMSY | 0.318 | 0.334 |
| F1986/FMSY | 1.39 | 1.20 |
| F1999/FMSY | 1.99 | 1.62 |
| F2004/FMSY | - | 2.70 |
| | | |
| R | 0.637 | 0.668 |
| K (LBS) | 2.12E+07 | 2.15E+07 |
| MSY (LBS) | 3.37E+06 | 3.59E+06 |

*** R is the intrinsic rate of growth; K is the carrying capacity

**Table 3.1.2.8.1.** Projected F, yield (millions of lbs), and biomass (millions of lbs) trajectories for the four continuity case scenarios.

| | | F2004 | | FMSY | | F Recovery | | Yield Recovery | |
|---|---|---|---|---|---|---|---|---|---|
| Year | FMSY | F | F/FMSY | F | F/FMSY | F | F/FMSY | F | F/FMSY |
| 2004 | 0.334 | 0.903 | 2.703 | 0.903 | 2.703 | 0.903 | 2.703 | 0.903 | 2.703 |
| 2005 | 0.334 | 0.903 | 2.703 | 0.903 | 2.703 | 0.903 | 2.703 | 0.903 | 2.703 |
| 2006 | 0.334 | 0.903 | 2.703 | 0.903 | 2.703 | 0.903 | 2.703 | 0.903 | 2.703 |
| 2007 | 0.334 | 0.903 | 2.703 | 0.334 | 1.000 | 0.222 | 0.665 | 0.444 | 1.328 |
| 2008 | 0.334 | 0.903 | 2.703 | 0.334 | 1.000 | 0.222 | 0.665 | 0.367 | 1.098 |
| 2009 | 0.334 | 0.903 | 2.703 | 0.334 | 1.000 | 0.222 | 0.665 | 0.285 | 0.853 |
| 2010 | 0.334 | 0.903 | 2.703 | 0.334 | 1.000 | 0.222 | 0.665 | 0.211 | 0.630 |
| 2011 | 0.334 | 0.903 | 2.703 | 0.334 | 1.000 | 0.222 | 0.665 | 0.152 | 0.455 |
| 2012 | 0.334 | 0.903 | 2.703 | 0.334 | 1.000 | 0.222 | 0.665 | 0.110 | 0.331 |
| 2013 | 0.334 | 0.903 | 2.703 | 0.334 | 1.000 | 0.222 | 0.665 | 0.084 | 0.251 |
| 2014 | 0.334 | 0.903 | 2.703 | 0.334 | 1.000 | 0.222 | 0.665 | 0.067 | 0.201 |
| 2015 | 0.334 | 0.903 | 2.703 | 0.334 | 1.000 | 0.222 | 0.665 | 0.057 | 0.172 |
| 2016 | 0.334 | 0.903 | 2.703 | 0.334 | 1.000 | 0.222 | 0.665 | 0.052 | 0.155 |
| Year | BMSY | Biomass | B/BMSY | Biomass | B/BMSY | Biomass | B/BMSY | Biomass | B/BMSY |
| 2004 | 10.761 | 4.320 | 0.401 | 4.320 | 0.401 | 4.320 | 0.401 | 4.320 | 0.401 |
| 2005 | 10.761 | 3.098 | 0.288 | 3.098 | 0.288 | 3.098 | 0.288 | 3.098 | 0.288 |
| 2006 | 10.761 | 2.288 | 0.213 | 2.288 | 0.213 | 2.288 | 0.213 | 2.288 | 0.213 |
| 2007 | 10.761 | 1.725 | 0.160 | 1.784 | 0.166 | 1.797 | 0.167 | 1.765 | 0.164 |
| 2008 | 10.761 | 1.318 | 0.122 | 2.320 | 0.216 | 2.597 | 0.241 | 2.020 | 0.188 |
| 2009 | 10.761 | 1.018 | 0.095 | 2.963 | 0.275 | 3.649 | 0.339 | 2.452 | 0.228 |
| 2010 | 10.761 | 0.792 | 0.074 | 3.706 | 0.344 | 4.950 | 0.460 | 3.167 | 0.294 |
| 2011 | 10.761 | 0.620 | 0.058 | 4.527 | 0.421 | 6.435 | 0.598 | 4.296 | 0.399 |
| 2012 | 10.761 | 0.488 | 0.045 | 5.391 | 0.501 | 7.988 | 0.742 | 5.961 | 0.554 |
| 2013 | 10.761 | 0.385 | 0.036 | 6.255 | 0.581 | 9.469 | 0.880 | 8.177 | 0.760 |
| 2014 | 10.761 | 0.305 | 0.028 | 7.075 | 0.657 | 10.761 | 1.000 | 10.761 | 1.000 |
| 2015 | 10.761 | 0.241 | 0.022 | 7.815 | 0.726 | 11.805 | 1.097 | 13.345 | 1.240 |
| 2016 | 10.761 | 0.192 | 0.018 | 8.456 | 0.786 | 12.597 | 1.171 | 15.562 | 1.446 |
| Year | MSY | Yield | Y/MSY | Yield | Y/MSY | Yield | Y/MSY | Yield | Y/MSY |
| 2004 | 3.595 | 3.410 | 0.949 | 3.410 | 0.949 | 3.410 | 0.949 | 3.410 | 0.949 |
| 2005 | 3.595 | 2.432 | 0.677 | 2.432 | 0.677 | 2.432 | 0.677 | 2.432 | 0.677 |
| 2006 | 3.595 | 1.814 | 0.504 | 1.814 | 0.504 | 1.814 | 0.504 | 1.814 | 0.504 |
| 2007 | 3.595 | 1.376 | 0.383 | 0.677 | 0.188 | 0.478 | 0.133 | 0.887 | 0.247 |
| 2008 | 3.595 | 1.057 | 0.294 | 0.873 | 0.243 | 0.681 | 0.190 | 0.887 | 0.247 |
| 2009 | 3.595 | 0.819 | 0.228 | 1.104 | 0.307 | 0.941 | 0.262 | 0.887 | 0.247 |
| 2010 | 3.595 | 0.639 | 0.178 | 1.365 | 0.380 | 1.251 | 0.348 | 0.887 | 0.247 |
| 2011 | 3.595 | 0.502 | 0.140 | 1.647 | 0.458 | 1.590 | 0.442 | 0.887 | 0.247 |
| 2012 | 3.595 | 0.395 | 0.110 | 1.937 | 0.539 | 1.930 | 0.537 | 0.887 | 0.247 |
| 2013 | 3.595 | 0.312 | 0.087 | 2.220 | 0.617 | 2.241 | 0.623 | 0.887 | 0.247 |
| 2014 | 3.595 | 0.247 | 0.069 | 2.482 | 0.690 | 2.503 | 0.696 | 0.887 | 0.247 |
| 2015 | 3.595 | 0.196 | 0.055 | 2.714 | 0.755 | 2.708 | 0.753 | 0.887 | 0.247 |
| 2016 | 3.595 | 0.156 | 0.043 | 2.911 | 0.810 | 2.860 | 0.796 | 0.887 | 0.247 |

**Table 3.2.1.2.1.** Catch series used for the SSASPM runs.

| YEAR | Commercial East (LBS) | Commercial West (LBS) | Recreational (Numbers) | Shrimp Bycatch (Numbers) |
|---|---|---|---|---|
| 1950-1962 | -1 | -1 | -1 | -1 |
| 1963 | 27700 | 20300 | -1 | -1 |
| 1964 | 30300 | 21200 | -1 | -1 |
| 1965 | 30100 | 18700 | -1 | -1 |
| 1966 | 15700 | 6000 | -1 | -1 |
| 1967 | 31800 | 14200 | -1 | -1 |
| 1968 | 63200 | 45300 | -1 | -1 |
| 1969 | 80500 | 24400 | -1 | -1 |
| 1970 | 75100 | 40000 | -1 | -1 |
| 1971 | 82000 | 43300 | -1 | -1 |
| 1972 | 72400 | 41900 | -1 | -1 |
| 1973 | 122100 | 49500 | -1 | -1 |
| 1974 | 115900 | 60200 | -1 | -1 |
| 1975 | 252200 | 98500 | -1 | -1 |
| 1976 | 221600 | 54500 | -1 | -1 |
| 1977 | 300337 | 175789 | -1 | -1 |
| 1978 | 258155 | 147082 | -1 | -1 |
| 1979 | 196791 | 198599 | -1 | -1 |
| 1980 | 143836 | 133743 | -1 | -1 |
| 1981 | 208578 | 104201 | 141888 | 6900000 |
| 1982 | 215646 | 131973 | 833154 | 6900000 |
| 1983 | 340912 | 145961 | 231710 | 6900000 |
| 1984 | 483215 | 832017 | 367066 | 6900000 |
| 1985 | 607023 | 722886 | 398400 | 6900000 |
| 1986 | 689625 | 939041 | 998551 | 6900000 |
| 1987 | 534518 | 1003433 | 1035306 | 6900000 |
| 1988 | 492997 | 991713 | 1375143 | 6900000 |
| 1989 | 481705 | 1002816 | 861223 | 6900000 |
| 1990 | 1489581 | 962643 | 1170574 | 6900000 |
| 1991 | 969399 | 808348 | 1165083 | 6900000 |
| 1992 | 1217900 | 1036278 | 1359566 | 6900000 |
| 1993 | 1667549 | 1024203 | 1202661 | 6900000 |
| 1994 | 1582072 | 1040183 | 989280 | 6900000 |
| 1995 | 1506085 | 654242 | 1229289 | 6900000 |
| 1996 | 1166437 | 651873 | 586062 | 6900000 |
| 1997 | 1040331 | 1072584 | 617878 | 6900000 |
| 1998 | 807987 | 895269 | 313724 | 6900000 |
| 1999 | 866821 | 1098219 | 421950 | 6900000 |
| 2000 | 699209 | 758230 | 333741 | 6900000 |
| 2001 | 791599 | 915733 | 623512 | 6900000 |
| 2002 | 1008662 | 997300 | 511965 | 6900000 |
| 2003 | 1153574 | 1260897 | 596534 | 6900000 |
| 2004 | 903434 | 1218992 | 815530 | 6900000 |

**Table 3.2.1.2.2.** Indices of abundance used for the SSASPM runs.

| YEAR | CMHL-E | CMHL-W | HB-E | HB-W | MRFSS |
|---|---|---|---|---|---|
| 1950-1985 | -1 | -1 | -1 | -1 | -1 |
| 1986 | -1 | -1 | 1.032 | 1.3384 | 2.0146 |
| 1987 | -1 | -1 | 0.9415 | 1.0085 | 1.0238 |
| 1988 | -1 | -1 | 2.0546 | 0.8242 | 0.8825 |
| 1989 | -1 | -1 | 1.0626 | 1.1914 | 0.6223 |
| 1990 | -1 | -1 | 1.6947 | 1.6901 | 2.4221 |
| 1991 | -1 | -1 | 1.9385 | 1.0368 | 1.4895 |
| 1992 | -1 | -1 | 2.2609 | 0.9378 | 1.7052 |
| 1993 | 1.3672 | 0.9743 | 1.4096 | 0.9196 | 1.9029 |
| 1994 | 1.4585 | 1.0884 | 1.1549 | 1.105 | 1.178 |
| 1995 | 1.1465 | 0.8371 | 1.1296 | 1.1262 | 1.7258 |
| 1996 | 1.0401 | 0.8129 | 0.648 | 0.8599 | 0.8839 |
| 1997 | 0.9461 | 1.0744 | 0.6969 | 0.9198 | 0.4752 |
| 1998 | 0.8455 | 1.0737 | 0.2477 | 0.8737 | 0.3558 |
| 1999 | 0.9007 | 0.9372 | 0.4683 | 0.6062 | 0.406 |
| 2000 | 0.7258 | 0.6425 | 0.3688 | 0.6771 | 0.3447 |
| 2001 | 0.8776 | 0.7942 | 0.3638 | 1.1784 | 0.3744 |
| 2002 | 0.8899 | 1.0319 | 0.5412 | 0.8844 | 0.3027 |
| 2003 | 0.9232 | 1.2665 | 0.4629 | 0.6573 | 0.3733 |
| 2004 | 0.8787 | 1.4669 | 0.5237 | 1.1653 | 0.5176 |

**Table 3.2.1.2.3.** Age composition matrices used for the SSASPM runs. The maximum effective sample size (SAMPLES) was fixed at 200.

| **A) COMMERCIAL EAST** | | Age | Age | Age | Age | Age | Age | Age | Age | Age | Age | Age | Age | Age | Age |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| YEAR | SAMPLES | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14+ |
| 1994 | 28 | 0 | 0 | 4 | 9 | 5 | 5 | 1 | 1 | 1 | 0 | 0 | 1 | 1 | 0 |
| 1995 | 6 | 0 | 0 | 0 | 0 | 2 | 2 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 |
| 1996 | 6 | 0 | 0 | 0 | 1 | 1 | 0 | 4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1997 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1998 | 138 | 9 | 42 | 67 | 6 | 7 | 4 | 0 | 0 | 0 | 1 | 1 | 1 | 0 | 0 |
| 1999 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2000 | 45 | 0 | 0 | 9 | 10 | 2 | 4 | 4 | 4 | 2 | 3 | 1 | 3 | 2 | 1 |
| 2001 | 200 | 0 | 47 | 165 | 256 | 266 | 177 | 121 | 74 | 40 | 44 | 19 | 17 | 9 | 15 |
| 2002 | 200 | 4 | 211 | 473 | 169 | 130 | 82 | 64 | 45 | 22 | 17 | 21 | 4 | 6 | 10 |
| 2003 | 200 | 1 | 76 | 435 | 800 | 310 | 141 | 188 | 90 | 57 | 13 | 13 | 11 | 6 | 4 |
| 2004 | 200 | 0 | 21 | 144 | 164 | 128 | 53 | 47 | 34 | 20 | 7 | 2 | 3 | 2 | 1 |

| **B) COMMERCIAL WEST** | | Age | Age | Age | Age | Age | Age | Age | Age | Age | Age | Age | Age | Age | Age |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| YEAR | SAMPLES | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14+ |
| 1994 | 64 | 0 | 0 | 6 | 9 | 20 | 9 | 7 | 4 | 0 | 2 | 2 | 3 | 1 | 1 |
| 1995 | 75 | 0 | 11 | 5 | 14 | 20 | 9 | 8 | 0 | 3 | 3 | 0 | 1 | 0 | 1 |
| 1996 | 71 | 0 | 1 | 21 | 9 | 10 | 11 | 5 | 3 | 3 | 4 | 1 | 1 | 2 | 0 |
| 1997 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1998 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1999 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2000 | 81 | 0 | 1 | 7 | 8 | 13 | 10 | 3 | 5 | 6 | 14 | 7 | 0 | 2 | 5 |
| 2001 | 102 | 0 | 1 | 10 | 15 | 14 | 12 | 7 | 6 | 9 | 8 | 4 | 2 | 7 | 7 |
| 2002 | 69 | 0 | 6 | 15 | 7 | 5 | 6 | 8 | 8 | 0 | 2 | 0 | 6 | 1 | 5 |
| 2003 | 200 | 0 | 9 | 51 | 245 | 74 | 44 | 30 | 28 | 19 | 9 | 14 | 10 | 4 | 5 |
| 2004 | 200 | 1 | 8 | 50 | 104 | 144 | 58 | 39 | 22 | 31 | 18 | 5 | 11 | 8 | 12 |

| **C) RECREATIONAL** | | Age | Age | Age | Age | Age | Age | Age | Age | Age | Age | Age | Age | Age | Age |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| YEAR | SAMPLES | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14+ |
| 1994 | 154 | 0 | 0 | 27 | 39 | 30 | 26 | 7 | 12 | 9 | 2 | 1 | 0 | 1 | 0 |
| 1995 | 192 | 2 | 18 | 41 | 40 | 44 | 17 | 13 | 4 | 8 | 3 | 0 | 0 | 1 | 1 |
| 1996 | 200 | 1 | 17 | 44 | 57 | 53 | 54 | 21 | 17 | 6 | 8 | 1 | 1 | 0 | 0 |
| 1997 | 46 | 0 | 8 | 3 | 12 | 6 | 8 | 5 | 2 | 2 | 0 | 0 | 0 | 0 | 0 |
| 1998 | 14 | 0 | 1 | 3 | 2 | 4 | 1 | 2 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1999 | 200 | 3 | 33 | 74 | 41 | 29 | 19 | 16 | 16 | 8 | 4 | 1 | 1 | 1 | 0 |
| 2000 | 200 | 0 | 6 | 34 | 51 | 53 | 26 | 16 | 19 | 12 | 7 | 1 | 3 | 1 | 1 |
| 2001 | 141 | 0 | 2 | 5 | 19 | 46 | 24 | 22 | 9 | 4 | 3 | 2 | 4 | 1 | 0 |
| 2002 | 200 | 0 | 15 | 45 | 24 | 55 | 36 | 42 | 26 | 5 | 3 | 3 | 2 | 2 | 0 |
| 2003 | 91 | 0 | 9 | 10 | 29 | 10 | 12 | 13 | 3 | 4 | 1 | 0 | 0 | 0 | 0 |
| 2004 | 129 | 0 | 0 | 7 | 41 | 48 | 10 | 16 | 3 | 1 | 2 | 1 | 0 | 0 | 0 |

**Table 3.2.1.2.4.** The data input file used for the SSASPM base run.

```
# GENERAL INFORMATION
# first and last year of data
  1950 2004
# number of years of prehistorical period
  31
# Enter 1 to calculate an average historic effort, 2 for a linear trend in historic effort, or 2 for exponential trend in historic effort
  2
# first and last age of data
  1    14
# number of seasons (months) per year
  12
# type of overall variance parameter (1 = log scale variance, 2 = observation scale variance, 0=force equal weighting)
  1
# spawning season (integer representing season/month of year when spawning occurs)
  6
# maturity schedue (fraction of each age class that is sexually mature
  1 1 1 1 1 1 1 1 1 1 1 1 1 1
# fecundity schedule (index of per capita fecundity of each age class)
# MILLIONS OF EGGS (Batch Fecundity at age * 87) 87=Spawning Frequency
  3.16 3.33 3.51 3.69 3.87 4.05 4.23 4.41 4.59 4.77 4.94 5.12 5.30 5.48

# CATCH INFORMATION
# number of catch data series (if there are no series, there should be no entries after the next line below)
  4
# pdf of observation error for each series (1) lognormal, (2) normal
  1 1 1 1
# units (1=numbers, 2=weight)
  2 2 1 1
# season (month) when fishing begins for each series
  1 1 1 1
# season (month) when fishing ends for each series
  12 12 12 12
# set of catch variance parameters each series is linked to
  1 1 1 1
# set of q parameters each series is linked to
  1 2 3 4
# set of s parameters each series is linked to
  1 2 3 4
# set of e parameters each series is linked to
  1 2 3 4
```

**Table 3.2.1.2.4. (continued)** The data input file used for the SSASPM base run.

```
#observed catches by set (column for year required)
#CM-E          CM-W           REC         SHRMP-BYC          YEAR
-1             -1             -1             -1              1950
#### REPEAT THE CATCH SERIES FOR EACH YEAR 1951-1962 ###
27700          20300          -1             -1              1963
30300          21200          -1             -1              1964
30100          18700          -1             -1              1965
15700          6000           -1             -1              1966
31800          14200          -1             -1              1967
63200          45300          -1             -1              1968
80500          24400          -1             -1              1969
75100          40000          -1             -1              1970
82000          43300          -1             -1              1971
72400          41900          -1             -1              1972
122100         49500          -1             -1              1973
115900         60200          -1             -1              1974
252200         98500          -1             -1              1975
221600         54500          -1             -1              1976
300337         175789         -1             -1              1977
258155         147082         -1             -1              1978
196791         198599         -1             -1              1979
143836         133743         -1             -1              1980
208578         104201         141888         6900000         1981
215646         131973         833154         6900000         1982
340912         145961         231710         6900000         1983
483215         832017         367066         6900000         1984
607023         722886         398400         6900000         1985
689625         939041         998551         6900000         1986
534518         1003433        1035306        6900000         1987
492997         991713         1375143        6900000         1988
481705         1002816        861223         6900000         1989
1489581        962643         1170574        6900000         1990
969399         808348         1165083        6900000         1991
1217900        1036278        1359566        6900000         1992
1667549        1024203        1202661        6900000         1993
1582072        1040183        989280         6900000         1994
1506085        654242         1229289        6900000         1995
1166437        651873         586062         6900000         1996
1040331        1072584        617878         6900000         1997
807987         895269         313724         6900000         1998
866821         1098219        421950         6900000         1999
699209         758230         333741         6900000         2000
791599         915733         623512         6900000         2001
1008662        997300         511965         6900000         2002
1153574        1260897        596534         6900000         2003
903434         1218992        815530         6900000         2004
```

**Table 3.2.1.2.4. (continued)** The data input file used for the SSASPM base run.

```
# annual scaling factors for observation variance (use this option to scale up the variance for observations based on very little (or
estimated) data) (column for year required)
#CM-E   CM-W    REC SHRMP-BYC  YEAR
1       1       1       1      1950
#### REPEAT THE SCALING FACTORS FOR EACH YEAR 1951-2004 ###
# INDICES OF ABUNDANCE (e.g., CPUE) If there are no series, there should be no entries between the comment lines.
# number of index data series
  5
# pdf of observation error for each series (1) lognormal, (2) normal
  1 1 1 1 1
# units (1=numbers, 2=weight)
  2 2 1 1 1
# season (month) when index begins for each series
  1 1 1 1 1
# season (month) when index ends for each series
  12 12 12 12 12
# option to (1) scale or (0) not to scale index observations
  0 0 0 0 0
# set of index variance parameters each series is linked to
  1 1 1 1 1
# set of q parameters each series is linked to
  5 6 7 8 9
# set of s parameters each series is linked to
  1 2 3 3 3
# observed indices by series (no column for year allowed)
#CMHL_E         CMHL_W          HB_E            HB_W            MRFSS           YEAR
-1.0000         -1.0000         -1.0000         -1.0000         -1.0000         1950
#### REPEAT PREVIOUS LINE FOR EACH YEAR 1951-1985 ###
-1.0000         -1.0000         1.0320          1.3384          2.0146          1986
-1.0000         -1.0000         0.9415          1.0085          1.0238          1987
-1.0000         -1.0000         2.0546          0.8242          0.8825          1988
-1.0000         -1.0000         1.0626          1.1914          0.6223          1989
-1.0000         -1.0000         1.6947          1.6901          2.4221          1990
-1.0000         -1.0000         1.9385          1.0368          1.4895          1991
-1.0000         -1.0000         2.2609          0.9378          1.7052          1992
1.3672          0.9743          1.4096          0.9196          1.9029          1993
1.4585          1.0884          1.1549          1.1050          1.1780          1994
1.1465          0.8371          1.1296          1.1262          1.7258          1995
1.0401          0.8129          0.6480          0.8599          0.8839          1996
0.9461          1.0744          0.6969          0.9198          0.4752          1997
0.8455          1.0737          0.2477          0.8737          0.3558          1998
0.9007          0.9372          0.4683          0.6062          0.4060          1999
0.7258          0.6425          0.3688          0.6771          0.3447          2000
0.8776          0.7942          0.3638          1.1784          0.3744          2001
0.8899          1.0319          0.5412          0.8844          0.3027          2002
0.9232          1.2665          0.4629          0.6573          0.3733          2003
0.8787          1.4669          0.5237          1.1653          0.5176          2004
```

**Table 3.2.1.2.4. (continued)** The data input file used for the SSASPM base run.

```
# annual scaling factors for observation variance (use this option to scale up the variance for obs based on very little data)
#CMHL_E        CMHL_W        HB_E          HB_W          MRFSS
1.0000  1.0000  1.0000  1.0000  1.0000  1950
#### REPEAT THESE SCALING FACTORS FOR EACH YEAR 1951-2004 ###

# EFFORT OBSERVATIONS If there are no series, there should be no entries between the comment lines.
# number of effort data series
   0
# AGE COMPOSITION OBSERVATIONS If there are no series, there should be no entries between the comment lines.
# number of age-composition series (If there are no series, there should be no more entries in this section)
  3
# first year in age-composition series
  1994
# probability densities used for age-comp. series (0 = ignore, 3 = multinomial, 8 = robustified normal)
  3 3 3
# units (only 1=numbers, no other options at this time)
  1 1 1
# season (month) when age collections begin for each series
  1 1 1
# season (month) when age collections end for each series
  12 12 12
# age composition data (MAXIMUM SAMPLE SIZE = 200)
#CM HL EAST
#FLEET  YEAR   SAMPLES AGE1   AGE2   AGE3   AGE4   AGE5   AGE6   AGE7   AGE8   AGE9   AGE10  AGE11  AGE12  AGE13  AGE14+
1       1994   28      0      0      4      9      5      5      1      1      1      0      0      1      1      0
1       1995   6       0      0      0      0      2      2      1      0      1      0      0      0      0      0
1       1996   6       0      0      0      1      1      0      4      0      0      0      0      0      0      0
1       1997   0       0      0      0      0      0      0      0      0      0      0      0      0      0      0
1       1998   138     9      42     67     6      7      4      0      0      0      1      1      1      0      0
1       1999   0       0      0      0      0      0      0      0      0      0      0      0      0      0      0
1       2000   45      0      0      9      10     2      4      4      4      2      3      1      3      2      1
1       2001   200     0      47     165    256    266    177    121    74     40     44     19     17     9      15
1       2002   200     4      211    473    169    130    82     64     45     22     17     21     4      6      10
1       2003   200     1      76     435    800    310    141    188    90     57     13     13     11     6      4
1       2004   200     0      21     144    164    128    53     47     34     20     7      2      3      2      1

#CM HL WEST
#FLEET  YEAR   SAMPLES AGE1   AGE2   AGE3   AGE4   AGE5   AGE6   AGE7   AGE8   AGE9   AGE10  AGE11  AGE12  AGE13  AGE14+
2       1994   64      0      0      6      9      20     9      7      4      0      2      2      3      1      1
2       1995   75      0      11     5      14     20     9      8      0      3      3      0      1      0      1
2       1996   71      0      1      21     9      10     11     5      3      3      4      1      1      2      0
2       1997   0       0      0      0      0      0      0      0      0      0      0      0      0      0      0
2       1998   0       0      0      0      0      0      0      0      0      0      0      0      0      0      0
2       1999   0       0      0      0      0      0      0      0      0      0      0      0      0      0      0
2       2000   81      0      1      7      8      13     10     3      5      6      14     7      0      2      5
2       2001   102     0      1      10     15     14     12     7      6      9      8      4      2      7      7
2       2002   69      0      6      15     7      5      6      8      8      0      2      0      6      1      5
2       2003   200     0      9      51     245    74     44     30     28     19     9      14     10     4      5
2       2004   200     1      8      50     104    144    58     39     22     31     18     5      11     8      12
```

**Table 3.2.1.2.4. (continued)** The data input file used for the SSASPM base run.

#REC

| #FLEET | YEAR | SAMPLES | AGE1 | AGE2 | AGE3 | AGE4 | AGE5 | AGE6 | AGE7 | AGE8 | AGE9 | AGE10 | AGE11 | AGE12 | AGE13 | AGE14+ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 3 | 1994 | 154 | 0 | 0 | 27 | 39 | 30 | 26 | 7 | 12 | 9 | 2 | 1 | 0 | 1 | 0 |
| 3 | 1995 | 192 | 2 | 18 | 41 | 40 | 44 | 17 | 13 | 4 | 8 | 3 | 0 | 0 | 1 | 1 |
| 3 | 1996 | 200 | 1 | 17 | 44 | 57 | 53 | 54 | 21 | 17 | 6 | 8 | 1 | 1 | 0 | 0 |
| 3 | 1997 | 46 | 0 | 8 | 3 | 12 | 6 | 8 | 5 | 2 | 2 | 0 | 0 | 0 | 0 | 0 |
| 3 | 1998 | 14 | 0 | 1 | 3 | 2 | 4 | 1 | 2 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| 3 | 1999 | 200 | 3 | 33 | 74 | 41 | 29 | 19 | 16 | 16 | 8 | 4 | 1 | 1 | 1 | 0 |
| 3 | 2000 | 200 | 0 | 6 | 34 | 51 | 53 | 26 | 16 | 19 | 12 | 7 | 1 | 3 | 1 | 1 |
| 3 | 2001 | 141 | 0 | 2 | 5 | 19 | 46 | 24 | 22 | 9 | 4 | 3 | 2 | 4 | 1 | 0 |
| 3 | 2002 | 200 | 0 | 15 | 45 | 24 | 55 | 36 | 42 | 26 | 5 | 3 | 3 | 2 | 2 | 0 |
| 3 | 2003 | 91 | 0 | 9 | 10 | 29 | 10 | 12 | 13 | 3 | 4 | 1 | 0 | 0 | 0 | 0 |
| 3 | 2004 | 129 | 0 | 0 | 7 | 41 | 48 | 10 | 16 | 3 | 1 | 2 | 1 | 0 | 0 | 0 |

**Table. 3.2.1.4.1.**. Parameter inputs for SSASPM base run.

```
# Total number of process parameters (must match number of entries in 'Specifications 1' section)
40
# Number of sets of each class of parameters (must be atleast 1)
# q (catchability)
# |     Effort
# |     |     Vulnerability (selectivity)
# |     |     |     catch observation variance scalar
# |     |     |     |     index variance scalar
# |     |     |     |     |     effort variance scalar
# |     |     |     |     |     |
  9     4     4     1     1     1
# Specifications 1: process parameters and observation error parameters
#===============================================================================================
#class (nature) of parameter (1=constant, 2-4 = polynom of degree x, 5=knife edge, 6=logistic, 7=gamma)
#  |       best estimate (or central tendency of prior)
#  |       |                lower bound    upper bound
#  |       |                |                |              phase to estimate (-1 = don't estimate)
#  |       |                |                |              | prior density (1= lognorm, 2=norm, 3=uniform)
#  |       |                |                |              |     |       prior variance
#  |       |                |                |              |     |       |
#-------------------------------------------------------------------------------------------------
# Natural mortality rate
   1       0.2500E+00       0.1000E-01       0.5000E+00    -1     1       0.2500E+00
# Recruitment (10=Beverton/Holt, 11=Ricker)
  10       0.1000E+07       0.1000E+04       0.1000E+10     1     3       0.1000E+01
  10       0.6000E+01       0.1100E+01       1.0000E+02     2     1      -0.8500E+00
# Growth (type 8 = von Bertalanfy/Richards, Linf, K, t0, m, a, b (weight=al^b)
   8       0.1699E+02       0.1000E-03       0.1000E+06    -1     0       0.1000E+01
   8       0.2000E+00       0.0000E+00       0.1000E+13    -1     0       0.1000E+01
   8      -0.3900E+01      -0.5000E+01       0.1000E+13    -1     0       0.1000E+01
   8       0.1000E+01       0.0000E+00       0.1000E+13    -1     0       0.1000E+01
   8       0.5957E-03       0.0000E+00       0.1000E+13    -1     0       0.1000E+01
   8       0.2870E+01       0.0000E+00       0.1000E+13    -1     0       0.1000E+01
```

**Table. 3.2.1.4.1.(continued)**. Parameter inputs for SSASPM base run.

```
# catchability
   #Catches (fix at 1 if E assumes Fishing Mortality)
   1       1.0000E+00       0.1000E-01       0.1000E+02    -1     0       0.1000E+01
   1       1.0000E+00       0.1000E-01       0.1000E+02    -1     0       0.1000E+01
   1       1.0000E+00       0.1000E-01       0.1000E+02    -1     0       0.1000E+01
   1       1.0000E+00       0.1000E-01       0.1000E+02    -1     0       0.1000E+01
   #Indices
   1       0.1000E-06       0.1000E-09       0.1000E+00     1     0       0.1000E+01
   1       0.1000E-06       0.1000E-09       0.1000E+00     1     0       0.1000E+01
   1       0.1000E-06       0.1000E-09       0.1000E+00     1     0       0.1000E+01
   1       0.1000E-06       0.1000E-09       0.1000E+00     1     0       0.1000E+01
   1       0.1000E-06       0.1000E-09       0.1000E+00     1     0       0.1000E+01
# effort for 'prehistoric' period when data is sparse
   1       0.00001E+00     -0.1000E-31       0.1000E+02    -1     0       0.1000E+01
   1       0.00001E+00     -0.1000E-31       0.1000E+02    -1     0       0.1000E+01
   1       0.00001E+00     -0.1000E-31       0.1000E+02    -1     0       0.1000E+01
   1       0.00001E+00     -0.1000E-31       0.1000E+02    -1     0       0.1000E+01
# effort for period with useful data (Set at assumed F va lues if q =1)
   1       0.01000E+00      0.1000E-02       5.000E+00      1     0       0.1000E+01
   1       0.01000E+00      0.1000E-02       5.000E+00      1     0       0.1000E+01
   1       0.01000E+00      0.1000E-02       5.000E+00      1     0       0.1000E+01
   1       0.01000E+00      0.1000E-02       5.000E+00      1     0       0.1000E+01
# vulnerability (selectivity)
#CM-EAST
   6       0.4046E+00       0.0000E-10       0.2000E+01     1     0       0.1000E+01
   6       2.6600E+00       0.5000E+00       0.4000E+01     3     0       0.6250E-01
#CM-WEST
   6       0.4046E+00       0.0000E-10       0.2000E+01     1     0       0.1000E+01
   6       2.6600E+00       0.5000E+00       0.4000E+01     3     0       0.6250E-01
#REC
   6       0.6329E+00       0.0000E-10       0.2000E+01     1     0       0.1000E+01
   6       3.0000E+00       0.5000E+00       0.4000E+01     3     0       0.6250E-01
#SHRIMP
   15       0.5000E+00       0.1000E-06       0.2000E+01   -4     0       0.1000E+01
   15       0.0100E+00       0.1000E-06       0.2000E+01   -4     0       0.1000E+01
   15       1.5000E+00       0.3000E+00       0.3000E+01   -3     0       0.6250E-01
   15       0.4150E+00       0.1000E-06       0.2000E+01   -4     0       0.1000E+01
   15       0.76938E+00      0.3000E+00       0.3000E+01   -3     0       0.6250E-01
```

**Table. 3.2.1.4.1.(continued)**. Parameter inputs for SSASPM base run.

```
# catch observation error variance scalar
   1       1.0000E+00       0.1000E+00       0.5000E+01    -1     0       0.1000E+01
# index observation error variance scalar
   1       2.0000E+00       0.1000E+00       0.5000E+01    -1     0       0.1000E+01
# effort observation error variance scalar
   1       1.0000E+00       0.1000E+00       0.5000E+01    -1     0       0.1000E+01
#===============================================================================
# Specifications 2: process ERROR parameters
#===============================================================================
#    best estimate (or central tendency of prior)
#    |                lower bound    upper bound
#    |                |                |              phase to estimate (-1 = don't estimate)
#    |                |                |              |  prior density (1= lognormal, 2=normal, 3=uniform)
#    |                |                |              |     |       prior variance
#    |                |                |              |     |       |
#--------------------------------------------------------------------------------
# overall variance (negative value indicates a CV)
    -0.2000E+00      -0.2000E+01      -0.1000E-01     2     0       0.1000E+01
# recruitment process variation parameters (allows year to year fluctuations)
#    correlation coefficient
     0.0000E+00      -0.1000E-31       0.9900E+00    -1     0       0.1000E+01
#    variance scalar (multiplied by overall variance)
     0.14820E+00      0.0000E+00       0.1000E+21    -1     0       0.1000E+01(
#    annual deviation parameters (last entry is arbitrary for deviations)
     0.0000E+00      -0.5000E+01       0.5000E+01     4     1       0.1000E+01
# catchability process variation parameters (allows year to year fluctuations)
#    correlation coefficients
     0.0000E+00      -0.1000E-31       0.9900E+00    -1     0       0.1000E+01
     0.0000E+00      -0.1000E-31       0.9900E+00    -1     0       0.1000E+01
     0.0000E+00      -0.1000E-31       0.9900E+00    -1     0       0.1000E+01
     0.0000E+00      -0.1000E-31       0.9900E+00    -1     0       0.1000E+01
     0.0000E+00      -0.1000E-31       0.9900E+00    -1     0       0.1000E+01
     0.0000E+00      -0.1000E-31       0.9900E+00    -1     0       0.1000E+01
     0.0000E+00      -0.1000E-31       0.9900E+00    -1     0       0.1000E+01
     0.0000E+00      -0.1000E-31       0.9900E+00    -1     0       0.1000E+01
     0.0000E+00      -0.1000E-31       0.9900E+00    -1     0       0.1000E+01
```

**Table. 3.2.1.4.1.(continued)**. Parameter inputs for SSASPM base run.

```
#    variance scalars (multiplied by overall variance)
     0.0000E+00      -0.1000E-31      0.1000E+21    -1     0      0.1000E+01
     0.0000E+00      -0.1000E-31      0.1000E+21    -1     0      0.1000E+01
     0.0000E+00      -0.1000E-31      0.1000E+21    -1     0      0.1000E+01
     0.0000E+00      -0.1000E-31      0.1000E+21    -1     0      0.1000E+01
     0.0000E+00      -0.1000E-31      0.1000E+21    -1     0      0.1000E+01
     0.0000E+00      -0.1000E-31      0.1000E+21    -1     0      0.1000E+01
     0.0000E+00      -0.1000E-31      0.1000E+21    -1     0      0.1000E+01
     0.0000E+00      -0.1000E-31      0.1000E+21    -1     0      0.1000E+01
     0.0000E+00      -0.1000E-31      0.1000E+21    -1     0      0.1000E+01
#    annual deviation parameters (last entry is arbitrary for deviations)
     0.0000E+00      -0.5000E+01      0.5000E+01    -1     0      0.1000E+01
     0.0000E+00      -0.5000E+01      0.5000E+01    -1     0      0.1000E+01
     0.0000E+00      -0.5000E+01      0.5000E+01    -1     0      0.1000E+01
     0.0000E+00      -0.5000E+01      0.5000E+01    -1     0      0.1000E+01
     0.0000E+00      -0.5000E+01      0.5000E+01    -1     0      0.1000E+01
     0.0000E+00      -0.5000E+01      0.5000E+01    -1     0      0.1000E+01
     0.0000E+00      -0.5000E+01      0.5000E+01    -1     0      0.1000E+01
     0.0000E+00      -0.5000E+01      0.5000E+01    -1     0      0.1000E+01
     0.0000E+00      -0.5000E+01      0.5000E+01    -1     0      0.1000E+01
# effort process variation parameters (allows year to year fluctuations)
#    correlation coefficients
     0.5000E+00       0.0000E+00      0.9900E+00    -1     0      0.1000E+01
     0.5000E+00       0.0000E+00      0.9900E+00    -1     0      0.1000E+01
     0.5000E+00       0.0000E+00      0.9900E+00    -1     0      0.1000E+01
     0.5000E+00       0.0000E+00      0.9900E+00    -1     0      0.1000E+01
#    variance scalars (multiplied by overall variance)
     0.22300E+00      0.0000E+00      0.1000E+21    -1     0      0.1000E+01
     0.22300E+00      0.0000E+00      0.1000E+21    -1     0      0.1000E+01
     0.22300E+00      0.0000E+00      0.1000E+21    -1     0      0.1000E+01
     0.040000+00      0.0000E+00      0.1000E+21    -1     0      0.1000E+01
#    annual deviation parameters (last entry is arbitrary for deviations)
     0.1000E-03      -0.5000E+01      0.5000E+01     2     1      0.1000E+01
     0.1000E-03      -0.5000E+01      0.5000E+01     2     1      0.1000E+01
     0.1000E-03      -0.5000E+01      0.5000E+01     2     1      0.1000E+01
     0.1000E-03      -0.5000E+01      0.5000E+01     2     1      0.1000E+01
```

**Table 3.2.1.5.1.** Stochastic equations used to define the state space age-structured production model, where the notation E is used to denote the value computed from the deterministic components of the model.

| **Variables** | **Description** |
|---|---|
| *Process functions for state variables* | |
| $M_{ay} = E[M_a]\, e^{-\varepsilon_{M,y}}, \quad \varepsilon_{M,y} = \rho_{M,y}\, \varepsilon_{M,y-1} + \eta_{M,y}$ | natural mortality rate |
| $N_{\alpha y} = E[N_{\alpha y}]\, e^{-\varepsilon_{R,y}}, \quad \varepsilon_{R,y} = \rho_R\, \varepsilon_{R,y-1} + \eta_{R,y}$ | recruitment of youngest age |
| $q_{iy} = E[q_{iy}]\, e^{-\varepsilon_{q,i,y}}, \quad \varepsilon_{q,i,y} = \rho_{q,i}\, \varepsilon_{q,i,y-1} + \eta_{q,i,y}$ | catchability for fleet *i* |
| $f_{iy} = E[f_{iy}]\, e^{-\varepsilon_{f,i,y}}, \quad \varepsilon_{f,i,y} = \rho_{f,i}\, \varepsilon_{f,i,y-1} + \eta_{f,i,y}$ | effort expended by fishery f |
| *Observation functions for data variables* | |
| $C_{ft} = \left( \delta\, q_{ft}\, E_{ft} \sum_{j=1}^{16} B_{t+j\delta} \right) e^{-\varepsilon_{C,f,t}}, \quad \varepsilon_{C,f,t} = \rho_{C,f}\, \varepsilon_{C,f,t-1} + \eta_{C,f,t}$ | catch of fleet *i* |
| $I_{ft} = \left( \delta q_{ft} \sum_{j=1}^{16} B_{t+j\delta} \right) e^{-\varepsilon_{I,f,t}}, \quad \varepsilon_{I,f,t} = \rho_{I,f}\, \varepsilon_{I,f,t-1} + \eta_{I,f,t}$ | CPUE of fleet *i* |

**Table 3.2.2.1.1** Fits to catches for the SSASPM model.

| | Commercial East (lbs) | | | Commercial West (lbs) | | | Recreational (Numbers) | | | Shrimp Bycatch (Numbers) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **YEAR** | **OBS** | **PRED** | **%DIFF** | **OBS** | **PRED** | **%DIFF** | **OBS** | **PRED** | **%DIFF** | **OBS** | **PRED** | **%DIFF** |
| 1981 | 208,580 | 114,370 | -45.17% | 104,200 | 61,615 | -40.87% | 141,890 | 272,030 | 91.72% | 6,900,000 | 4,866,500 | -29.47% |
| 1982 | 215,650 | 238,420 | 10.56% | 131,970 | 148,250 | 12.34% | 833,150 | 585,220 | -29.76% | 6,900,000 | 6,031,900 | -12.58% |
| 1983 | 340,910 | 369,790 | 8.47% | 145,960 | 221,060 | 51.45% | 231,710 | 338,070 | 45.90% | 6,900,000 | 6,389,400 | -7.40% |
| 1984 | 483,220 | 502,730 | 4.04% | 832,020 | 640,110 | -23.07% | 367,070 | 408,310 | 11.23% | 6,900,000 | 6,287,900 | -8.87% |
| 1985 | 607,020 | 610,380 | 0.55% | 722,890 | 740,130 | 2.38% | 398,400 | 489,990 | 22.99% | 6,900,000 | 5,424,100 | -21.39% |
| 1986 | 689,620 | 656,660 | -4.78% | 939,040 | 889,610 | -5.26% | 998,550 | 868,330 | -13.04% | 6,900,000 | 6,296,000 | -8.75% |
| 1987 | 534,520 | 563,810 | 5.48% | 1,003,400 | 952,860 | -5.04% | 1,035,300 | 1,010,900 | -2.36% | 6,900,000 | 7,893,800 | 14.40% |
| 1988 | 493,000 | 537,360 | 9.00% | 991,710 | 951,780 | -4.03% | 1,375,100 | 1,181,400 | -14.09% | 6,900,000 | 5,593,000 | -18.94% |
| 1989 | 481,700 | 597,950 | 24.13% | 1,002,800 | 959,240 | -4.34% | 861,220 | 967,310 | 12.32% | 6,900,000 | 7,105,800 | 2.98% |
| 1990 | 1,489,600 | 1,114,800 | -25.16% | 962,640 | 934,370 | -2.94% | 1,170,600 | 1,122,100 | -4.14% | 6,900,000 | 6,674,700 | -3.27% |
| 1991 | 969,400 | 1,027,200 | 5.96% | 808,350 | 863,920 | 6.87% | 1,165,100 | 1,186,400 | 1.83% | 6,900,000 | 7,359,800 | 6.66% |
| 1992 | 1,217,900 | 1,203,400 | -1.19% | 1,036,300 | 996,810 | -3.81% | 1,359,600 | 1,311,500 | -3.54% | 6,900,000 | 6,471,800 | -6.21% |
| 1993 | 1,667,500 | 1,506,700 | -9.64% | 1,024,200 | 1,022,000 | -0.21% | 1,202,700 | 1,232,800 | 2.50% | 6,900,000 | 5,837,800 | -15.39% |
| 1994 | 1,582,100 | 1,536,400 | -2.89% | 1,040,200 | 1,020,700 | -1.87% | 989,280 | 1,133,100 | 14.54% | 6,900,000 | 5,829,200 | -15.52% |
| 1995 | 1,506,100 | 1,380,400 | -8.35% | 654,240 | 733,820 | 12.16% | 1,229,300 | 1,072,300 | -12.77% | 6,900,000 | 5,937,900 | -13.94% |
| 1996 | 1,166,400 | 1,158,400 | -0.69% | 651,870 | 692,060 | 6.17% | 586,060 | 657,300 | 12.16% | 6,900,000 | 6,768,500 | -1.91% |
| 1997 | 1,040,300 | 1,002,800 | -3.60% | 1,072,600 | 912,090 | -14.96% | 617,880 | 585,280 | -5.28% | 6,900,000 | 7,368,700 | 6.79% |
| 1998 | 807,990 | 797,300 | -1.32% | 895,270 | 780,500 | -12.82% | 313,720 | 374,070 | 19.24% | 6,900,000 | 7,514,600 | 8.91% |
| 1999 | 866,820 | 784,450 | -9.50% | 1,098,200 | 787,690 | -28.27% | 421,950 | 397,550 | -5.78% | 6,900,000 | 5,572,700 | -19.24% |
| 2000 | 699,210 | 726,010 | 3.83% | 758,230 | 739,880 | -2.42% | 333,740 | 400,100 | 19.88% | 6,900,000 | 7,735,200 | 12.10% |
| 2001 | 791,600 | 808,570 | 2.14% | 915,730 | 985,420 | 7.61% | 623,510 | 616,550 | -1.12% | 6,900,000 | 6,117,500 | -11.34% |
| 2002 | 1,008,700 | 905,260 | -10.25% | 997,300 | 1,082,100 | 8.50% | 511,960 | 582,520 | 13.78% | 6,900,000 | 5,540,100 | -19.71% |
| 2003 | 1,153,600 | 952,820 | -17.40% | 1,260,900 | 1,089,400 | -13.60% | 596,530 | 609,450 | 2.17% | 6,900,000 | 4,188,300 | -39.30% |
| 2004 | 903,430 | 787,160 | -12.87% | 1,219,000 | 979,170 | -19.67% | 815,530 | 688,120 | -15.62% | 6,900,000 | 4,918,500 | -28.72% |

**Table 3.2.2.1.2** Fits to indices for the SSASPM model.

| | Commercial HL East | | | Commercial HL West | | | Headboat East | | | Headboat West | | | MRFSS | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **YEAR** | **OBS** | **PRED** | **%DIFF** | **OBS** | **PRED** | **%DIFF** | **OBS** | **PRED** | **%DIFF** | **OBS** | **PRED** | **%DIFF** | **OBS** | **PRED** | **%DIFF** |
| 1981 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 1982 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 1983 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 1984 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 1985 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 1986 | - | - | - | - | - | - | 1.03 | 0.92 | -11.0% | 1.34 | 1.08 | -19.47% | 2.01 | 0.88 | -56.2% |
| 1987 | - | - | - | - | - | - | 0.94 | 0.86 | -8.9% | 1.01 | 1.01 | -0.32% | 1.02 | 0.82 | -19.7% |
| 1988 | - | - | - | - | - | - | 2.05 | 0.83 | -59.6% | 0.82 | 0.97 | 18.07% | 0.88 | 0.80 | -9.8% |
| 1989 | - | - | - | - | - | - | 1.06 | 0.87 | -18.4% | 1.19 | 1.02 | -14.59% | 0.62 | 0.83 | 33.7% |
| 1990 | - | - | - | - | - | - | 1.69 | 0.88 | -48.2% | 1.69 | 1.03 | -39.05% | 2.42 | 0.84 | -65.2% |
| 1991 | - | - | - | - | - | - | 1.94 | 0.88 | -54.6% | 1.04 | 1.03 | -0.40% | 1.49 | 0.85 | -43.3% |
| 1992 | - | - | - | - | - | - | 2.26 | 0.90 | -60.2% | 0.94 | 1.05 | 12.38% | 1.71 | 0.86 | -49.4% |
| 1993 | 1.37 | 1.12 | -18.5% | 0.97 | 1.06 | 9.2% | 1.41 | 0.90 | -36.2% | 0.92 | 1.05 | 14.64% | 1.90 | 0.86 | -54.7% |
| 1994 | 1.46 | 1.05 | -28.3% | 1.09 | 1.04 | -4.2% | 1.16 | 0.86 | -25.3% | 1.11 | 1.01 | -8.52% | 1.18 | 0.83 | -29.8% |
| 1995 | 1.15 | 0.96 | -16.0% | 0.84 | 0.98 | 17.3% | 1.13 | 0.80 | -29.6% | 1.13 | 0.93 | -17.27% | 1.73 | 0.76 | -55.8% |
| 1996 | 1.04 | 0.92 | -12.0% | 0.81 | 0.93 | 14.0% | 0.65 | 0.75 | 15.5% | 0.86 | 0.88 | 2.18% | 0.88 | 0.72 | -18.7% |
| 1997 | 0.95 | 0.91 | -4.0% | 1.08 | 0.90 | -16.3% | 0.70 | 0.73 | 5.4% | 0.92 | 0.86 | -6.23% | 0.48 | 0.71 | 48.4% |
| 1998 | 0.85 | 0.96 | 13.3% | 1.07 | 0.91 | -15.0% | 0.25 | 0.76 | 207.9% | 0.87 | 0.90 | 2.75% | 0.36 | 0.73 | 106.2% |
| 1999 | 0.90 | 1.00 | 11.4% | 0.94 | 0.97 | 3.5% | 0.47 | 0.81 | 73.0% | 0.61 | 0.95 | 57.14% | 0.41 | 0.78 | 91.9% |
| 2000 | 0.73 | 0.99 | 36.2% | 0.64 | 1.01 | 57.7% | 0.37 | 0.82 | 123.4% | 0.68 | 0.97 | 43.10% | 0.35 | 0.79 | 129.9% |
| 2001 | 0.88 | 0.97 | 10.6% | 0.79 | 1.00 | 25.6% | 0.36 | 0.80 | 119.0% | 1.18 | 0.94 | -20.53% | 0.37 | 0.77 | 104.5% |
| 2002 | 0.89 | 1.03 | 15.5% | 1.03 | 0.98 | -5.5% | 0.54 | 0.81 | 49.1% | 0.89 | 0.95 | 7.25% | 0.30 | 0.78 | 156.2% |
| 2003 | 0.92 | 1.00 | 8.0% | 1.27 | 1.00 | -21.2% | 0.46 | 0.82 | 76.1% | 0.66 | 0.96 | 45.67% | 0.37 | 0.78 | 109.8% |
| 2004 | 0.88 | 0.89 | 0.8% | 1.47 | 0.96 | -34.7% | 0.52 | 0.75 | 42.2% | 1.17 | 0.87 | -24.96% | 0.52 | 0.72 | 38.2% |

**Table. 3.2.2.2.1**. Selected parameter estimates and error from the SSASPM base model.

| | B/B0 | | Recruitment Devs | |
|---|---|---|---|---|
| **YEAR** | **Value** | **Std Dev** | **Value** | **Std Dev** |
| 1950 | 1.000 | 0.000 | 0 | 0 |
| 1951 | 0.999 | 0.000 | 0 | 0 |
| 1952 | 0.995 | 0.001 | 0 | 0 |
| 1953 | 0.988 | 0.002 | 0 | 0 |
| 1954 | 0.980 | 0.003 | 0 | 0 |
| 1955 | 0.971 | 0.004 | 0 | 0 |
| 1956 | 0.961 | 0.006 | 0 | 0 |
| 1957 | 0.949 | 0.007 | 0 | 0 |
| 1958 | 0.937 | 0.009 | 0 | 0 |
| 1959 | 0.925 | 0.011 | 0 | 0 |
| 1960 | 0.912 | 0.013 | 0 | 0 |
| 1961 | 0.898 | 0.014 | 0 | 0 |
| 1962 | 0.885 | 0.016 | 0 | 0 |
| 1963 | 0.872 | 0.018 | 0 | 0 |
| 1964 | 0.858 | 0.020 | 0 | 0 |
| 1965 | 0.845 | 0.022 | 0 | 0 |
| 1966 | 0.831 | 0.023 | 0 | 0 |
| 1967 | 0.818 | 0.025 | 0 | 0 |
| 1968 | 0.805 | 0.026 | 0 | 0 |
| 1969 | 0.792 | 0.028 | 0 | 0 |
| 1970 | 0.779 | 0.030 | 0 | 0 |
| 1971 | 0.767 | 0.031 | 0 | 0 |
| 1972 | 0.754 | 0.032 | 0 | 0 |
| 1973 | 0.742 | 0.034 | 0 | 0 |
| 1974 | 0.730 | 0.035 | 0 | 0 |
| 1975 | 0.718 | 0.036 | 0 | 0 |
| 1976 | 0.706 | 0.038 | 0 | 0 |
| 1977 | 0.694 | 0.039 | 0 | 0 |
| 1978 | 0.683 | 0.040 | 0 | 0 |
| 1979 | 0.672 | 0.041 | 0 | 0 |
| 1980 | 0.661 | 0.042 | 0 | 0 |
| 1981 | 0.662 | 0.068 | 0.076 | 0.285 |
| 1982 | 0.679 | 0.074 | 0.223 | 0.272 |
| 1983 | 0.686 | 0.075 | 0.248 | 0.258 |
| 1984 | 0.674 | 0.072 | 0.193 | 0.249 |
| 1985 | 0.625 | 0.065 | -0.013 | 0.241 |
| 1986 | 0.639 | 0.065 | 0.293 | 0.199 |
| 1987 | 0.720 | 0.071 | 0.612 | 0.164 |
| 1988 | 0.649 | 0.063 | 0.051 | 0.171 |
| 1989 | 0.708 | 0.067 | 0.520 | 0.134 |
| 1990 | 0.711 | 0.067 | 0.389 | 0.126 |
| 1991 | 0.748 | 0.070 | 0.531 | 0.117 |
| 1992 | 0.708 | 0.067 | 0.268 | 0.119 |
| 1993 | 0.646 | 0.061 | 0.121 | 0.123 |
| 1994 | 0.606 | 0.058 | 0.161 | 0.121 |
| 1995 | 0.573 | 0.056 | 0.151 | 0.122 |
| 1996 | 0.603 | 0.060 | 0.390 | 0.114 |
| 1997 | 0.637 | 0.065 | 0.433 | 0.114 |
| 1998 | 0.621 | 0.065 | 0.265 | 0.125 |
| 1999 | 0.551 | 0.061 | -0.116 | 0.131 |
| 2000 | 0.658 | 0.078 | 0.609 | 0.118 |
| 2001 | 0.646 | 0.083 | 0.247 | 0.129 |
| 2002 | 0.581 | 0.081 | -0.065 | 0.153 |
| 2003 | 0.476 | 0.073 | -0.527 | 0.216 |
| 2004 | 0.440 | 0.075 | -0.148 | 0.269 |

| ***Parameter*** | ***Value*** | ***Standard Deviation*** |
|---|---|---|
| Virgin Biomass | 2.15E+14 | 2.05E+13 |
| Alpha | 15.15 | 7.85 |
| $r_0$ | 1.41e+07 | 1.34+06 |
| $F_{2004}$ | 0.57 | 0.14 |
| $SSB_{2004}$ | 9.47E+13 | 1.80E+13 |
| Overall Variance (CV) | 0.395 | 2.4184e-02 |

**Table 3.2.2.3.1.** Spawing stock biomass (SSB) and SSB relative to $SSB_{MSY}$ and $SSB_{SPR30\%}$.

| YEAR | SSB | $SSB/SSB_{MSY}$ | $SSB/SSB_{SPR30\%}$ | $SSB/SSB_{VIRGIN}$ |
|---|---|---|---|---|
| 1981 | 1.43E+08 | 2.707 | 2.640 | 0.662 |
| 1982 | 1.46E+08 | 2.776 | 2.707 | 0.679 |
| 1983 | 1.48E+08 | 2.804 | 2.735 | 0.686 |
| 1984 | 1.45E+08 | 2.758 | 2.690 | 0.674 |
| 1985 | 1.34E+08 | 2.554 | 2.491 | 0.625 |
| 1986 | 1.38E+08 | 2.613 | 2.548 | 0.639 |
| 1987 | 1.55E+08 | 2.944 | 2.871 | 0.720 |
| 1988 | 1.40E+08 | 2.656 | 2.590 | 0.649 |
| 1989 | 1.52E+08 | 2.895 | 2.823 | 0.708 |
| 1990 | 1.53E+08 | 2.908 | 2.835 | 0.711 |
| 1991 | 1.61E+08 | 3.060 | 2.984 | 0.748 |
| 1992 | 1.52E+08 | 2.893 | 2.822 | 0.708 |
| 1993 | 1.39E+08 | 2.641 | 2.576 | 0.646 |
| 1994 | 1.30E+08 | 2.476 | 2.415 | 0.606 |
| 1995 | 1.23E+08 | 2.342 | 2.284 | 0.573 |
| 1996 | 1.30E+08 | 2.467 | 2.405 | 0.603 |
| 1997 | 1.37E+08 | 2.604 | 2.539 | 0.637 |
| 1998 | 1.34E+08 | 2.541 | 2.478 | 0.621 |
| 1999 | 1.19E+08 | 2.255 | 2.199 | 0.551 |
| 2000 | 1.42E+08 | 2.693 | 2.626 | 0.658 |
| 2001 | 1.39E+08 | 2.640 | 2.575 | 0.646 |
| 2002 | 1.25E+08 | 2.376 | 2.317 | 0.581 |
| 2003 | 1.03E+08 | 1.948 | 1.899 | 0.476 |
| 2004 | 9.47E+07 | 1.800 | 1.755 | 0.440 |

**Table 3.2.2.4.1.** Fishing mortality rate (F) and F relative to $F_{MSY}$ and $F_{SPR30\%}$..

| YEAR | F | $F/F_{MSY}$ | $F/F_{SPR30\%}$ |
|---|---|---|---|
| 1981 | 3.77E-01 | 4.33E-01 | 4.42E-01 |
| 1982 | 4.16E-01 | 4.78E-01 | 4.88E-01 |
| 1983 | 4.25E-01 | 4.89E-01 | 4.99E-01 |
| 1984 | 4.39E-01 | 5.05E-01 | 5.15E-01 |
| 1985 | 4.58E-01 | 5.26E-01 | 5.37E-01 |
| 1986 | 4.20E-01 | 4.83E-01 | 4.93E-01 |
| 1987 | 3.77E-01 | 4.34E-01 | 4.43E-01 |
| 1988 | 3.98E-01 | 4.58E-01 | 4.68E-01 |
| 1989 | 3.72E-01 | 4.28E-01 | 4.37E-01 |
| 1990 | 3.67E-01 | 4.22E-01 | 4.31E-01 |
| 1991 | 3.63E-01 | 4.18E-01 | 4.26E-01 |
| 1992 | 3.92E-01 | 4.50E-01 | 4.60E-01 |
| 1993 | 4.25E-01 | 4.89E-01 | 4.99E-01 |
| 1994 | 4.28E-01 | 4.92E-01 | 5.02E-01 |
| 1995 | 4.44E-01 | 5.10E-01 | 5.21E-01 |
| 1996 | 4.10E-01 | 4.71E-01 | 4.81E-01 |
| 1997 | 4.14E-01 | 4.76E-01 | 4.86E-01 |
| 1998 | 4.93E-01 | 5.66E-01 | 5.78E-01 |
| 1999 | 5.25E-01 | 6.03E-01 | 6.16E-01 |
| 2000 | 3.95E-01 | 4.54E-01 | 4.63E-01 |
| 2001 | 3.78E-01 | 4.35E-01 | 4.44E-01 |
| 2002 | 4.81E-01 | 5.53E-01 | 5.65E-01 |
| 2003 | 6.00E-01 | 6.90E-01 | 7.04E-01 |
| 2004 | 5.69E-01 | 6.54E-01 | 6.68E-01 |

**Table 3.2.2.5.1.** Annual recruitment estimates.

| YEAR | RECRUITMENT (Age 1) |
|---|---|
| 1981 | 1.47E+07 |
| 1982 | 1.70E+07 |
| 1983 | 1.75E+07 |
| 1984 | 1.65E+07 |
| 1985 | 1.34E+07 |
| 1986 | 1.81E+07 |
| 1987 | 2.50E+07 |
| 1988 | 1.44E+07 |
| 1989 | 2.28E+07 |
| 1990 | 2.02E+07 |
| 1991 | 2.33E+07 |
| 1992 | 1.80E+07 |
| 1993 | 1.54E+07 |
| 1994 | 1.59E+07 |
| 1995 | 1.57E+07 |
| 1996 | 1.98E+07 |
| 1997 | 2.08E+07 |
| 1998 | 1.77E+07 |
| 1999 | 1.20E+07 |
| 2000 | 2.45E+07 |
| 2001 | 1.74E+07 |
| 2002 | 1.27E+07 |
| 2003 | 7.92E+06 |
| 2004 | 1.13E+07 |

**Table 3.2.2.8.1.** Management and biomass status benchmarks for the SSASPM base case.

| Benchmark | Value |
|---|---|
| $SSB_{MSY}$ | 5.26E+07 |
| $SSB_{30\%SPR}$ | 5.40E+07 |
| $SSB_{1962}/SSB_{MSY}$ | 2.71 |
| $SSB_{1999}/SSB_{MSY}$ | 2.25 |
| $SSB_{2004}/SSB_{MSY}$ | 1.80 |
| $SSB_{1962}/SSB_{30\%SPR}$ | 2.64 |
| $SSB_{1999}/SSB_{30\%SPR}$ | 2.20 |
| $SSB_{2004}/SSB_{30\%SPR}$ | 1.75 |
| | |
| $F_{MSY}$ | 0.87 |
| $F_{30\%SPR}$ | 0.85 |
| $F_{1962}/F_{MSY}$ | 0.43 |
| $F_{1999}/F_{MSY}$ | 0.60 |
| $F_{2004}/F_{MSY}$ | 0.65 |
| $F_{1962}/F_{30\%SPR}$ | 0.44 |
| $F_{1999}/F_{30\%SPR}$ | 0.62 |
| $F_{2004}/F_{30\%SPR}$ | 0.67 |
| | |
| STEEPNESS | 0.79 |
| MSY (LBS) | 5.54E+06 |
| F0.1 | 0.85 |
| Virgin Recruitment ($R_0$) | 1.41E+07 |

**Table 3.2.2.9.1.1** Results of the "Current Yield" projection of the SSASPM base model.

$SSB_{MSY}$ = 5.26E+14 $SSB_{SPR30\%}$ = 5.40E+14 MSY = 5.52E+06 $F_{MSY}$ = 0.865 $F_{2004}$ = 0.569

| YEAR | YIELD | LCI | UCI | $SSB/SSB_{MSY}$ | LCI | UCI | $SSB/SSB_{SPR30\%}$ | LCI | UCI | Recuitment | LCI | UCI |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2005 | 5.84E+06 | 5.84E+06 | 5.84E+06 | 1.75 | 1.44 | 2.37 | 1.70 | 1.40 | 2.31 | 1.46E+07 | 6.95E+06 | 2.47E+07 |
| 2006 | 4.35E+06 | 4.35E+06 | 4.35E+06 | 1.75 | 1.32 | 2.64 | 1.70 | 1.29 | 2.57 | 1.45E+07 | 6.75E+06 | 2.43E+07 |
| 2007 | 4.35E+06 | 4.35E+06 | 4.35E+06 | 1.79 | 1.33 | 2.83 | 1.75 | 1.30 | 2.75 | 1.46E+07 | 6.81E+06 | 2.44E+07 |
| 2008 | 4.35E+06 | 4.35E+06 | 4.35E+06 | 1.83 | 1.37 | 3.05 | 1.79 | 1.33 | 2.97 | 1.50E+07 | 7.36E+06 | 2.56E+07 |
| 2009 | 4.35E+06 | 4.35E+06 | 4.35E+06 | 1.87 | 1.38 | 3.25 | 1.82 | 1.34 | 3.17 | 1.50E+07 | 7.04E+06 | 2.65E+07 |
| 2010 | 4.35E+06 | 4.35E+06 | 4.35E+06 | 1.90 | 1.39 | 3.35 | 1.85 | 1.36 | 3.26 | 1.50E+07 | 6.97E+06 | 2.43E+07 |
| 2011 | 4.35E+06 | 4.35E+06 | 4.35E+06 | 1.93 | 1.49 | 3.44 | 1.88 | 1.45 | 3.35 | 1.53E+07 | 7.38E+06 | 2.48E+07 |
| 2012 | 4.35E+06 | 4.35E+06 | 4.35E+06 | 1.95 | 1.56 | 3.43 | 1.90 | 1.52 | 3.34 | 1.52E+07 | 7.37E+06 | 2.51E+07 |
| 2013 | 4.35E+06 | 4.35E+06 | 4.35E+06 | 1.97 | 1.58 | 3.61 | 1.92 | 1.54 | 3.51 | 1.55E+07 | 6.75E+06 | 2.65E+07 |
| 2014 | 4.35E+06 | 4.35E+06 | 4.35E+06 | 1.99 | 1.67 | 3.58 | 1.94 | 1.62 | 3.49 | 1.51E+07 | 7.14E+06 | 2.61E+07 |
| 2015 | 4.35E+06 | 4.35E+06 | 4.35E+06 | 2.01 | 1.65 | 3.52 | 1.96 | 1.60 | 3.43 | 1.49E+07 | 6.75E+06 | 2.54E+07 |
| 2016 | 4.35E+06 | 4.35E+06 | 4.35E+06 | 2.02 | 1.64 | 3.75 | 1.97 | 1.60 | 3.65 | 1.57E+07 | 7.24E+06 | 2.62E+07 |

**Table 3.2.2.9.1.2.** Results of the "Current F" projection of the SSASPM base model.

$SSB_{MSY}$ = 5.26E+14 $SSB_{SPR30\%}$ = 5.40E+14 MSY = 5,52E+06 $F_{MSY}$ = 0.865 $F_{2004}$ = 0.569

| YEAR | YIELD | LCI | UCI | $SSB/SSB_{MSY}$ | LCI | UCI | $SSB/SSB_{SPR30\%}$ | LCI | UCI | Recuitment | LCI | UCI |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2005 | 5.94E+06 | 4.54E+06 | 8.69E+06 | 1.74 | 1.49 | 2.24 | 1.70 | 1.45 | 2.19 | 1.46E+07 | 6.95E+06 | 2.47E+07 |
| 2006 | 5.72E+06 | 4.27E+06 | 8.75E+06 | 1.68 | 1.37 | 2.28 | 1.64 | 1.34 | 2.22 | 1.45E+07 | 6.71E+06 | 2.42E+07 |
| 2007 | 5.54E+06 | 4.14E+06 | 8.45E+06 | 1.64 | 1.34 | 2.33 | 1.60 | 1.31 | 2.27 | 1.45E+07 | 6.78E+06 | 2.45E+07 |
| 2008 | 5.44E+06 | 4.08E+06 | 8.55E+06 | 1.61 | 1.31 | 2.37 | 1.57 | 1.28 | 2.31 | 1.48E+07 | 7.26E+06 | 2.55E+07 |
| 2009 | 5.37E+06 | 3.99E+06 | 8.71E+06 | 1.59 | 1.28 | 2.37 | 1.55 | 1.25 | 2.31 | 1.47E+07 | 6.92E+06 | 2.61E+07 |
| 2010 | 5.32E+06 | 4.01E+06 | 8.27E+06 | 1.58 | 1.29 | 2.37 | 1.53 | 1.25 | 2.31 | 1.47E+07 | 6.86E+06 | 2.37E+07 |
| 2011 | 5.29E+06 | 4.12E+06 | 8.57E+06 | 1.56 | 1.32 | 2.38 | 1.52 | 1.29 | 2.32 | 1.49E+07 | 7.17E+06 | 2.41E+07 |
| 2012 | 5.26E+06 | 4.19E+06 | 8.49E+06 | 1.56 | 1.32 | 2.31 | 1.52 | 1.28 | 2.25 | 1.47E+07 | 7.10E+06 | 2.44E+07 |
| 2013 | 5.25E+06 | 4.03E+06 | 8.72E+06 | 1.55 | 1.31 | 2.40 | 1.51 | 1.28 | 2.34 | 1.50E+07 | 6.54E+06 | 2.54E+07 |
| 2014 | 5.23E+06 | 4.08E+06 | 8.52E+06 | 1.55 | 1.32 | 2.35 | 1.51 | 1.28 | 2.29 | 1.45E+07 | 6.81E+06 | 2.50E+07 |
| 2015 | 5.22E+06 | 3.95E+06 | 8.39E+06 | 1.54 | 1.27 | 2.32 | 1.50 | 1.24 | 2.26 | 1.43E+07 | 6.53E+06 | 2.43E+07 |
| 2016 | 5.22E+06 | 4.07E+06 | 8.60E+06 | 1.54 | 1.31 | 2.38 | 1.50 | 1.28 | 2.32 | 1.50E+07 | 7.01E+06 | 2.51E+07 |

**Table 3.2.2.9.2.1** Results of the "Current Yield" projection of the SSASPM sensitivity case. This projection uses recruitment parameters estimating using only recent data (1986-2004).

$SSB_{MSY}$ = 6.54E+14 $SSB_{SPR30\%}$ = 6.91E+14 MSY = 7.07E+06 $F_{MSY}$ = 0.886 $F_{2004}$ = 0.569

| YEAR | YIELD | LCI | UCI | $SSB/SSB_{MSY}$ | LCI | UCI | $SSB/SSB_{SPR30\%}$ | LCI | UCI | Recuitment | LCI | UCI |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2005 | 5.84E+06 | 5.84E+06 | 5.84E+06 | 1.53 | 1.22 | 2.15 | 1.45 | 1.15 | 2.04 | 1.79E+07 | 8.53E+06 | 3.04E+07 |
| 2006 | 4.35E+06 | 4.35E+06 | 4.35E+06 | 1.64 | 1.21 | 2.53 | 1.55 | 1.14 | 2.39 | 1.80E+07 | 8.36E+06 | 3.02E+07 |
| 2007 | 4.35E+06 | 4.35E+06 | 4.35E+06 | 1.77 | 1.30 | 2.82 | 1.68 | 1.23 | 2.66 | 1.83E+07 | 8.52E+06 | 3.05E+07 |
| 2008 | 4.35E+06 | 4.35E+06 | 4.35E+06 | 1.89 | 1.41 | 3.12 | 1.79 | 1.34 | 2.95 | 1.90E+07 | 9.32E+06 | 3.23E+07 |
| 2009 | 4.35E+06 | 4.35E+06 | 4.35E+06 | 1.99 | 1.49 | 3.40 | 1.89 | 1.41 | 3.22 | 1.91E+07 | 8.95E+06 | 3.37E+07 |
| 2010 | 4.35E+06 | 4.35E+06 | 4.35E+06 | 2.09 | 1.57 | 3.56 | 1.97 | 1.49 | 3.37 | 1.91E+07 | 8.89E+06 | 3.11E+07 |
| 2011 | 4.35E+06 | 4.35E+06 | 4.35E+06 | 2.17 | 1.72 | 3.68 | 2.05 | 1.63 | 3.48 | 1.96E+07 | 9.45E+06 | 3.17E+07 |
| 2012 | 4.35E+06 | 4.35E+06 | 4.35E+06 | 2.24 | 1.83 | 3.76 | 2.12 | 1.73 | 3.55 | 1.95E+07 | 9.44E+06 | 3.22E+07 |
| 2013 | 4.35E+06 | 4.35E+06 | 4.35E+06 | 2.30 | 1.91 | 3.93 | 2.18 | 1.81 | 3.72 | 1.99E+07 | 8.69E+06 | 3.39E+07 |
| 2014 | 4.35E+06 | 4.35E+06 | 4.35E+06 | 2.35 | 2.02 | 3.98 | 2.23 | 1.91 | 3.76 | 1.94E+07 | 9.15E+06 | 3.35E+07 |
| 2015 | 4.35E+06 | 4.35E+06 | 4.35E+06 | 2.40 | 2.03 | 3.95 | 2.27 | 1.92 | 3.73 | 1.91E+07 | 8.67E+06 | 3.26E+07 |
| 2016 | 4.35E+06 | 4.35E+06 | 4.35E+06 | 2.44 | 2.06 | 4.17 | 2.31 | 1.94 | 3.94 | 2.02E+07 | 9.25E+06 | 3.37E+07 |

**Table 3.2.2.9.2.2** Results of the "Current F" projection of the SSASPM sensitivity case. This projection uses recruitment parameters estimating using only recent data (1986-2004).

$SSB_{MSY}$ = 6.54E+14 $SSB_{SPR30\%}$ = 6.91E+14 MSY = 7.07E+06 $F_{MSY}$ = 0.886 $F_{2004}$ = 0.569

| YEAR | YIELD | LCI | UCI | $SSB/SSB_{MSY}$ | LCI | UCI | $SSB/SSB_{SPR30\%}$ | LCI | UCI | Recuitment | LCI | UCI |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2005 | 6.62E+06 | 4.91E+06 | 1.00E+07 | 1.50 | 1.25 | 2.00 | 1.42 | 1.18 | 1.89 | 1.79E+07 | 8.53E+06 | 3.04E+07 |
| 2006 | 6.60E+06 | 4.80E+06 | 1.04E+07 | 1.52 | 1.20 | 2.11 | 1.43 | 1.14 | 2.00 | 1.79E+07 | 8.38E+06 | 3.02E+07 |
| 2007 | 6.52E+06 | 4.76E+06 | 1.02E+07 | 1.53 | 1.23 | 2.22 | 1.44 | 1.16 | 2.10 | 1.81E+07 | 8.45E+06 | 3.03E+07 |
| 2008 | 6.51E+06 | 4.79E+06 | 1.04E+07 | 1.54 | 1.24 | 2.30 | 1.45 | 1.17 | 2.18 | 1.86E+07 | 9.10E+06 | 3.19E+07 |
| 2009 | 6.53E+06 | 4.79E+06 | 1.07E+07 | 1.55 | 1.23 | 2.33 | 1.46 | 1.17 | 2.21 | 1.86E+07 | 8.71E+06 | 3.28E+07 |
| 2010 | 6.55E+06 | 4.89E+06 | 1.03E+07 | 1.55 | 1.26 | 2.36 | 1.47 | 1.19 | 2.23 | 1.85E+07 | 8.65E+06 | 2.99E+07 |
| 2011 | 6.56E+06 | 5.08E+06 | 1.07E+07 | 1.56 | 1.31 | 2.39 | 1.47 | 1.24 | 2.26 | 1.89E+07 | 9.07E+06 | 3.05E+07 |
| 2012 | 6.58E+06 | 5.21E+06 | 1.07E+07 | 1.56 | 1.32 | 2.33 | 1.48 | 1.25 | 2.20 | 1.87E+07 | 8.99E+06 | 3.09E+07 |
| 2013 | 6.59E+06 | 5.04E+06 | 1.10E+07 | 1.56 | 1.32 | 2.43 | 1.48 | 1.25 | 2.30 | 1.90E+07 | 8.31E+06 | 3.22E+07 |
| 2014 | 6.60E+06 | 5.13E+06 | 1.08E+07 | 1.57 | 1.33 | 2.39 | 1.48 | 1.26 | 2.26 | 1.85E+07 | 8.63E+06 | 3.17E+07 |
| 2015 | 6.60E+06 | 4.98E+06 | 1.06E+07 | 1.57 | 1.29 | 2.36 | 1.48 | 1.22 | 2.23 | 1.82E+07 | 8.28E+06 | 3.10E+07 |
| 2016 | 6.61E+06 | 5.16E+06 | 1.09E+07 | 1.57 | 1.34 | 2.42 | 1.48 | 1.26 | 2.29 | 1.91E+07 | 8.91E+06 | 3.20E+07 |

# 7. Figures

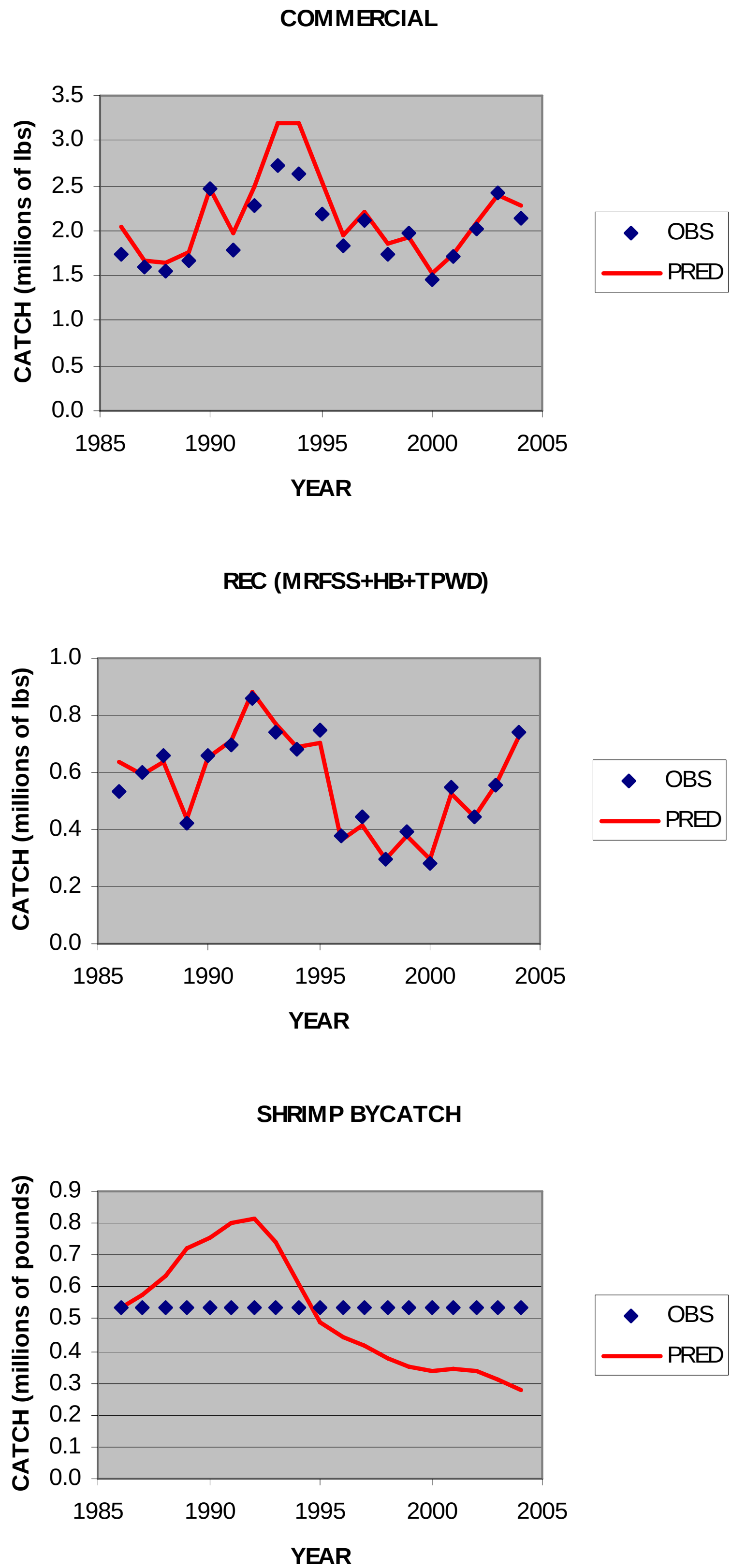



**Figure 3.1.2.1.1.** Model fits to the catch series for the continuity case.

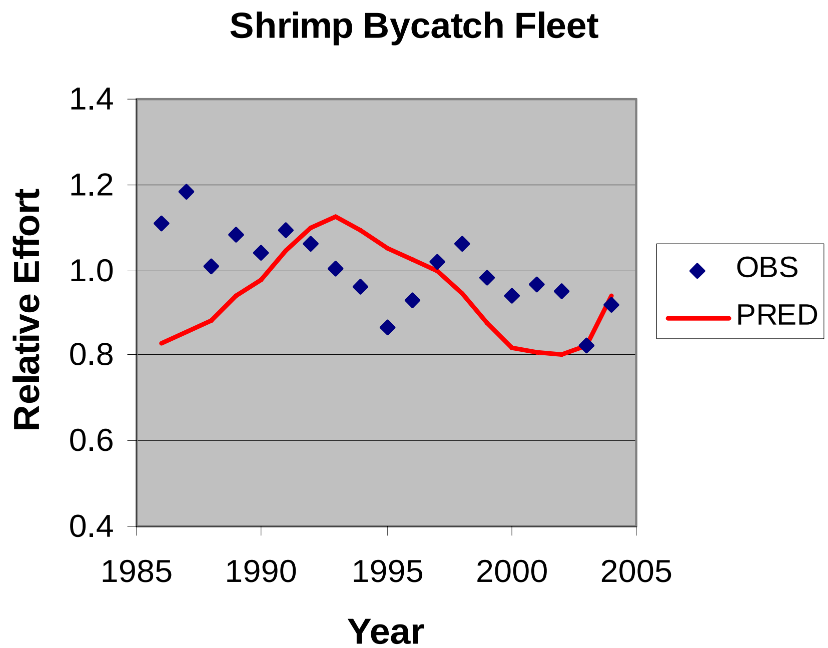
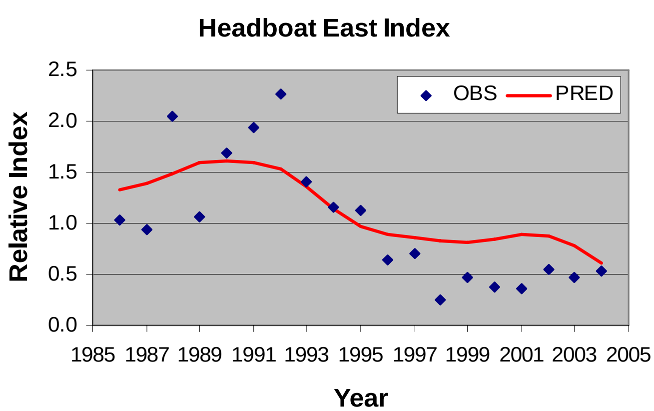



**Figure 3.1.2.1.2.** Model fits to the effort series for the continuity case.



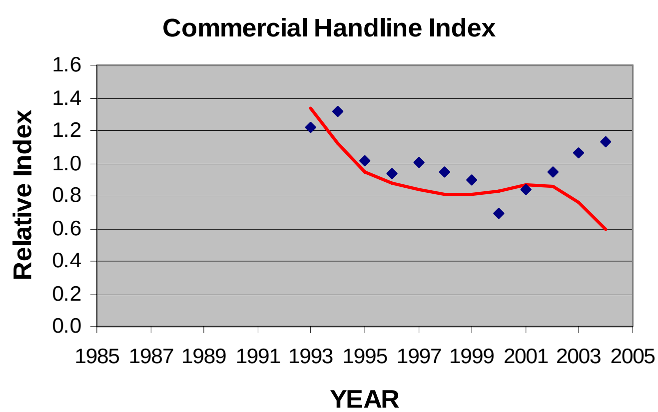




**Figure 3.1.2.1.3.** Model fits to the indices of abundance for the continuity case.

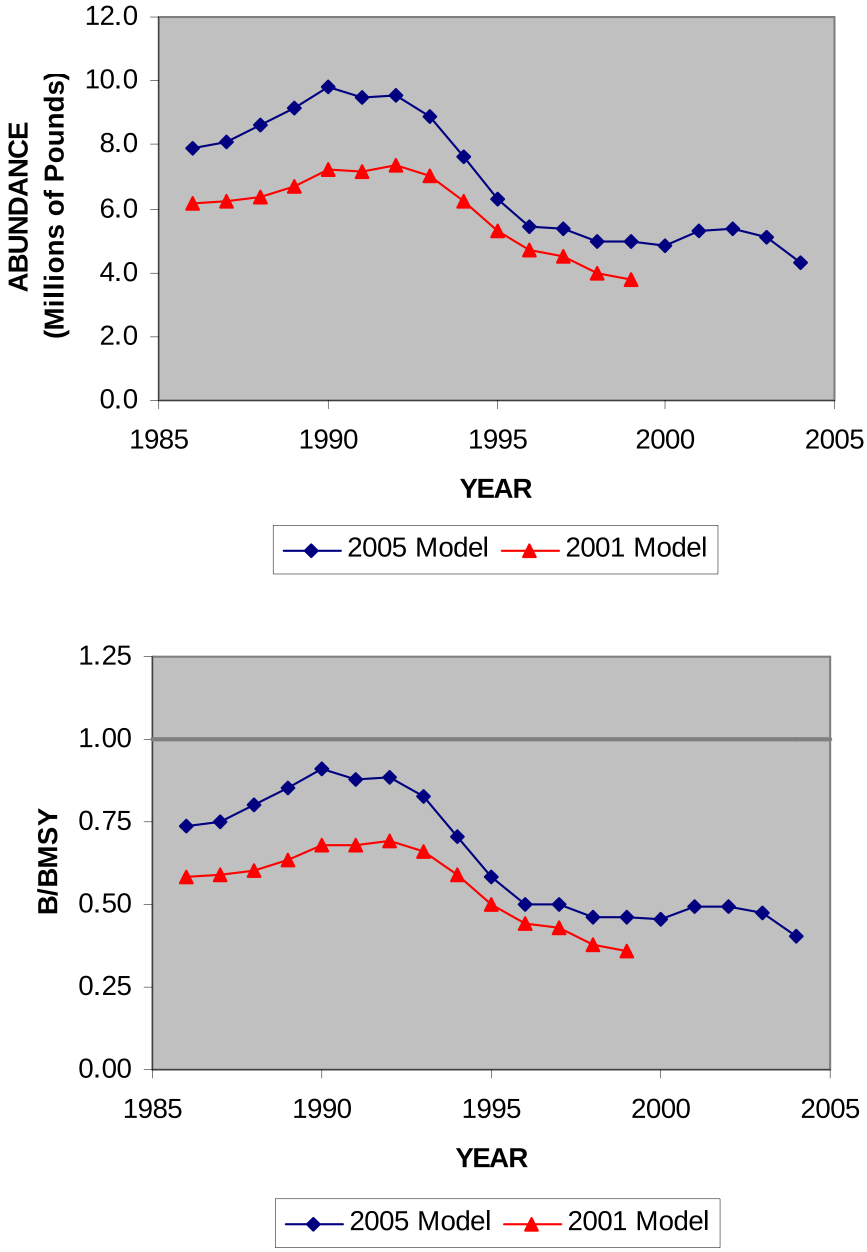
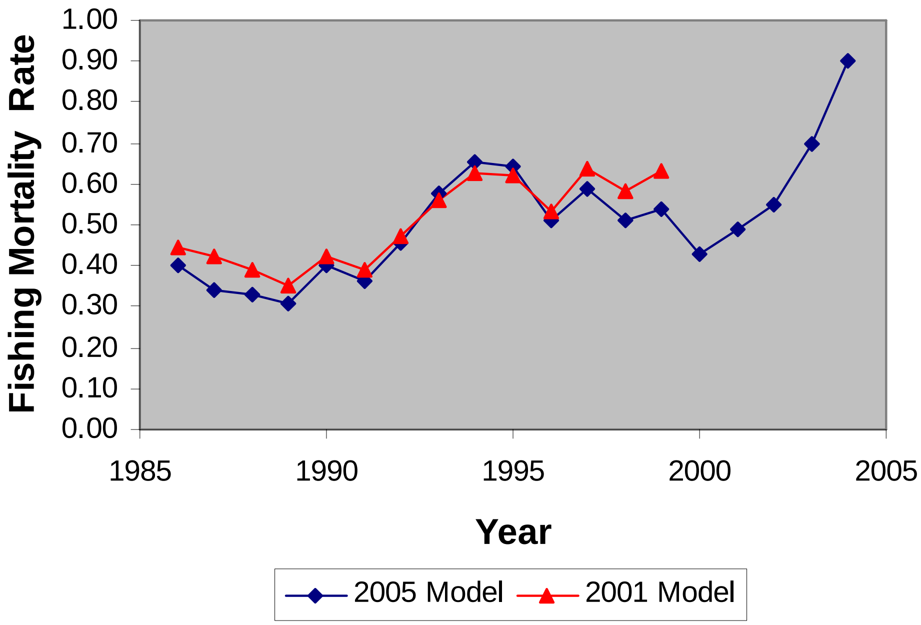



**Figure 3.1.2.3.1.** Comparison of the population biomass trajectories for the continuity case (2005) and the 2001 assessment base run.



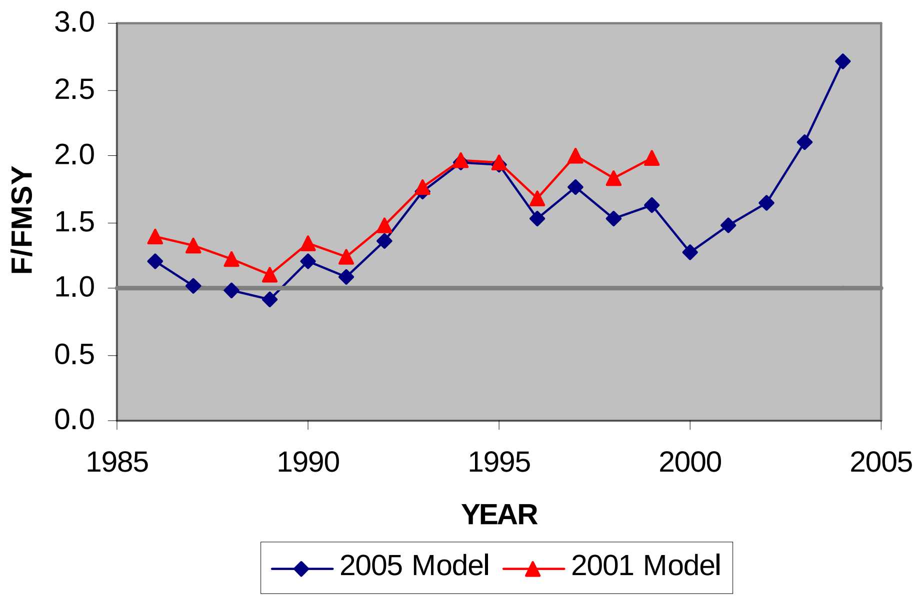




**Figure 3.1.2.4.1.** Comparison of the trend in fishing mortality rates for the continuity case (2005) and the 2001 assessment base run.

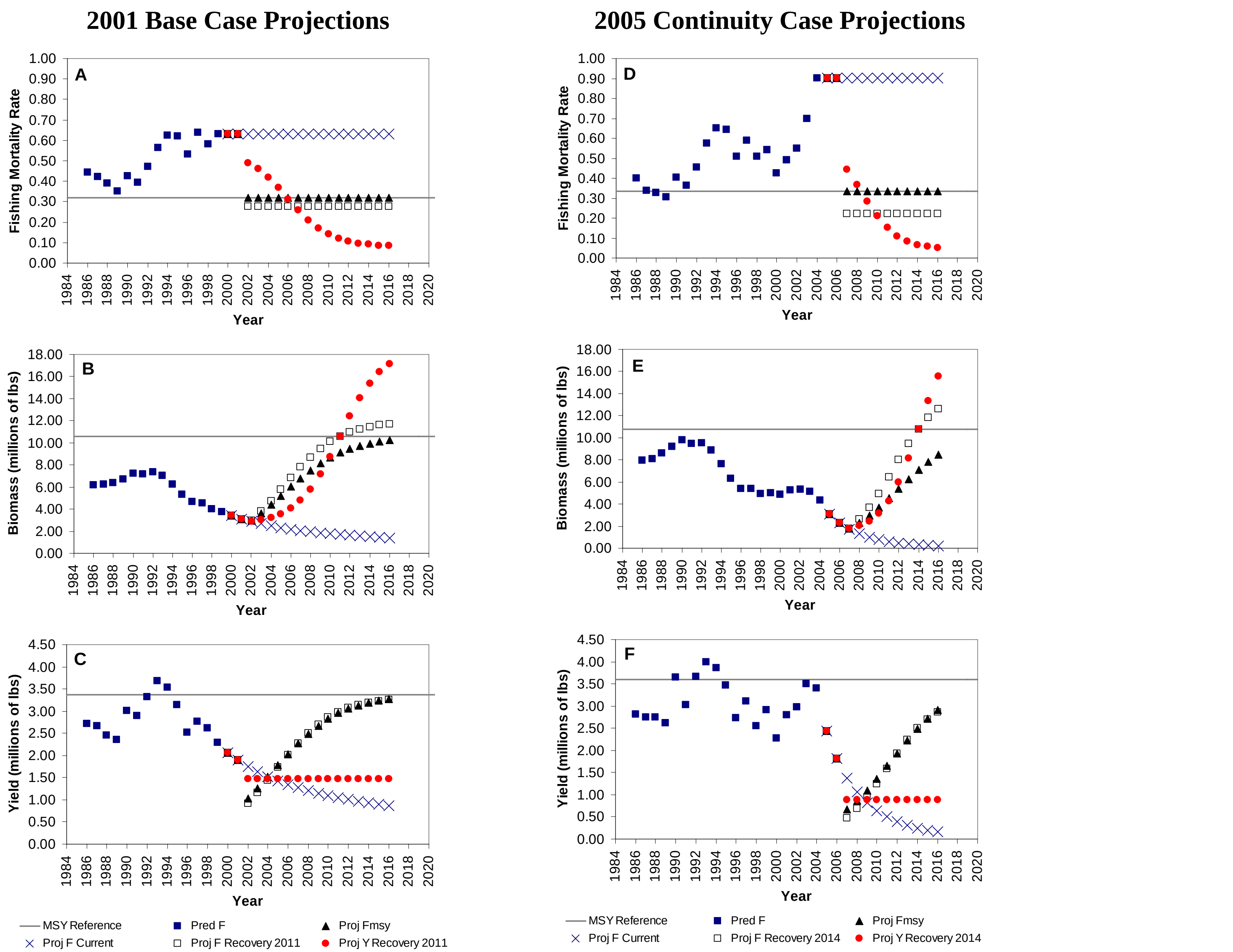



**Figure 3.1.2.8.1.** Projected fishing mortality, yield, and biomass trajectories for the four projection scenarios. Panels A-C are the 2001 base model projections. Panels D-F are the 2005 continuity case projections. Symbol Key: estimated value= blue square; current F projection = blue X; $F_{MSY}$ projection = black triangle; F-recovery projection = open square; Yield-recovery projection = red circle.

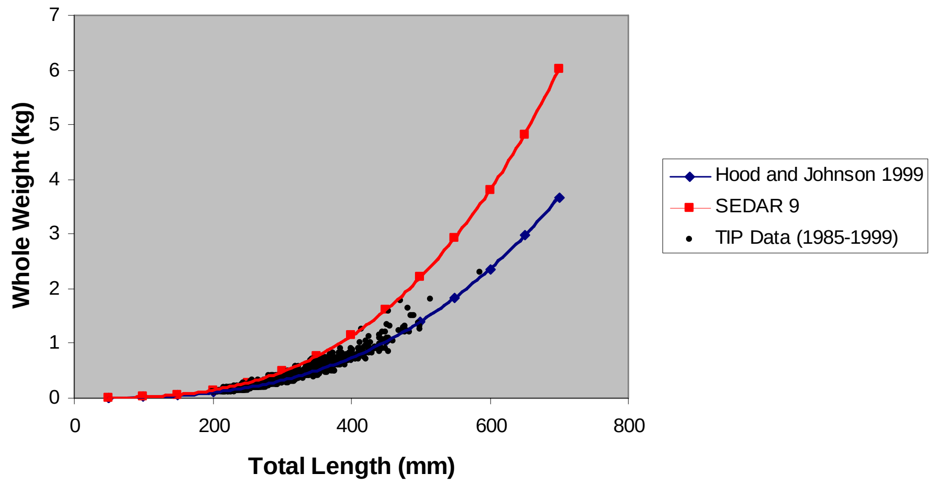
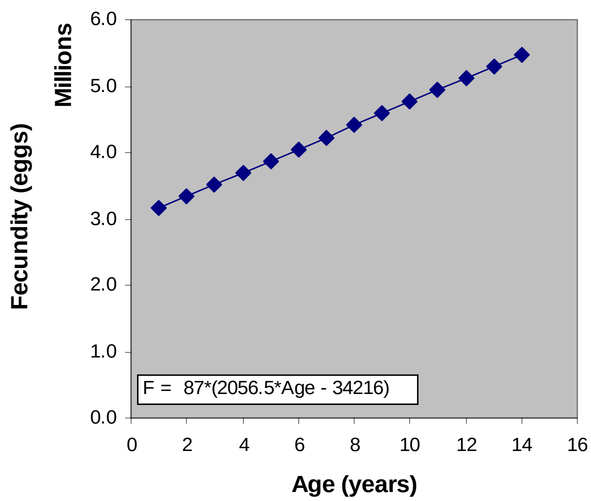



**Figure 3.2.1.2.1.** Comparison of length-weight relationships.



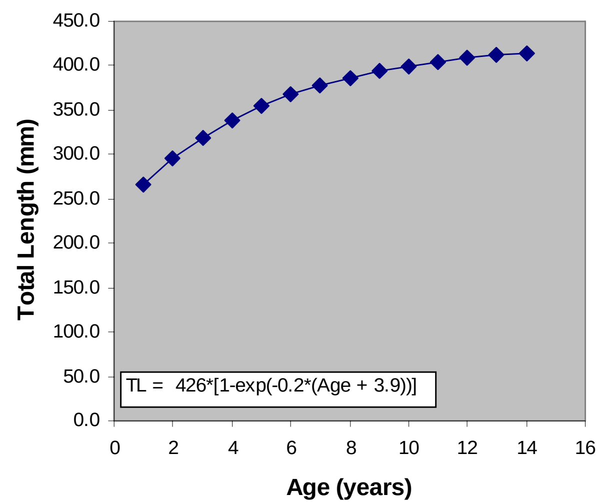




**Figure 3.2.1.2.2.** Annual fecundity at age. **Figure 3.2.1.2.3** Length at age relationship.

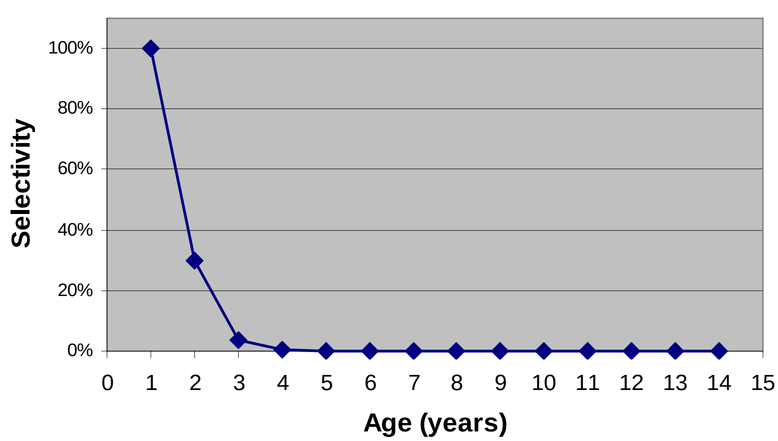



**Figure 3.2.1.2.4.** Fixed selectivity function used for shrimp bycatch fleet.

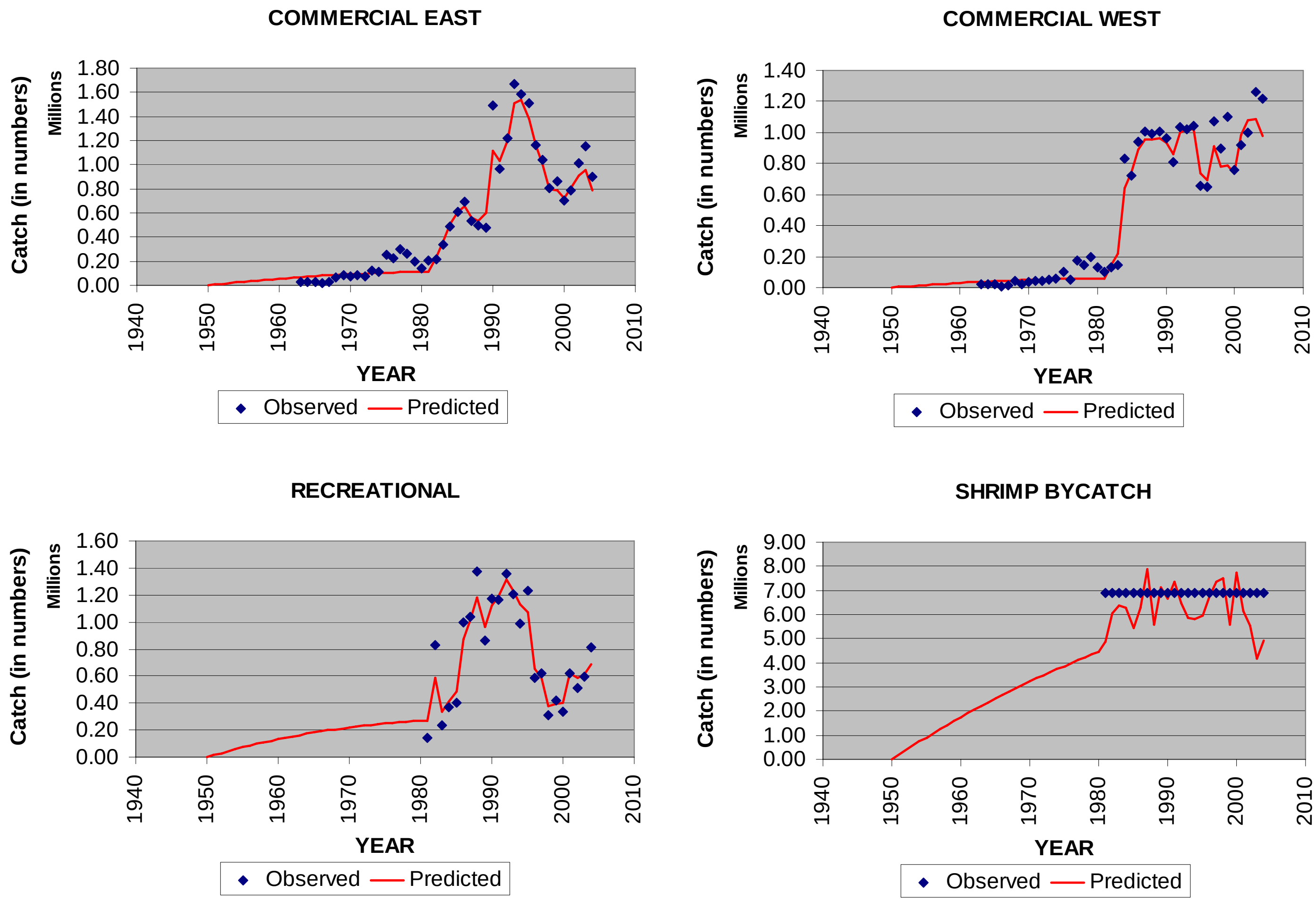



**Figure 3.2.2.1.1** Model fits to the catch series for the SSASPM base model.

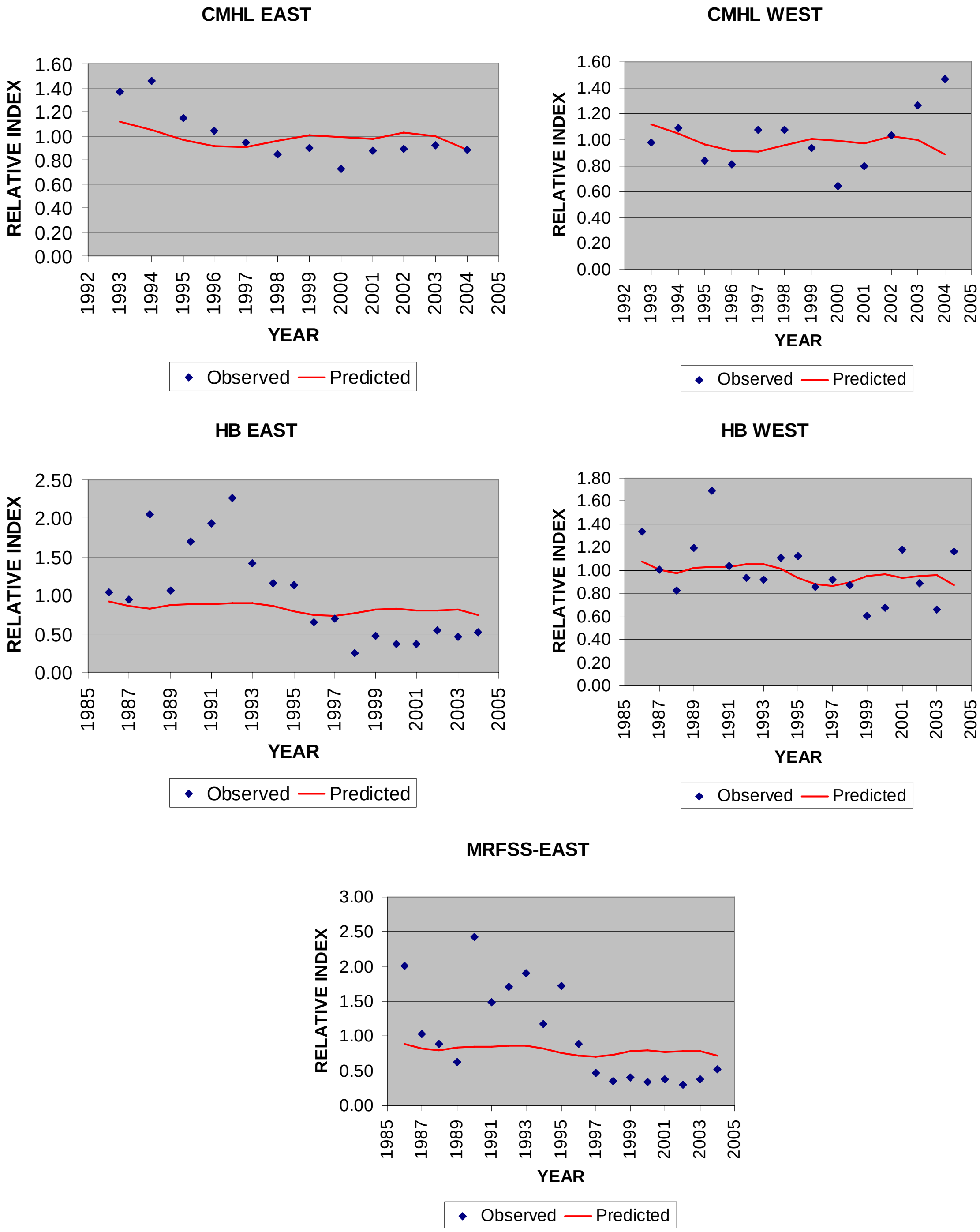



**Figure 3.2.2.1.2** Model fits to the indices of abundance for the SSASPM base model.

*AGE COMPOSTION COMMERCIAL EAST FISHERY*

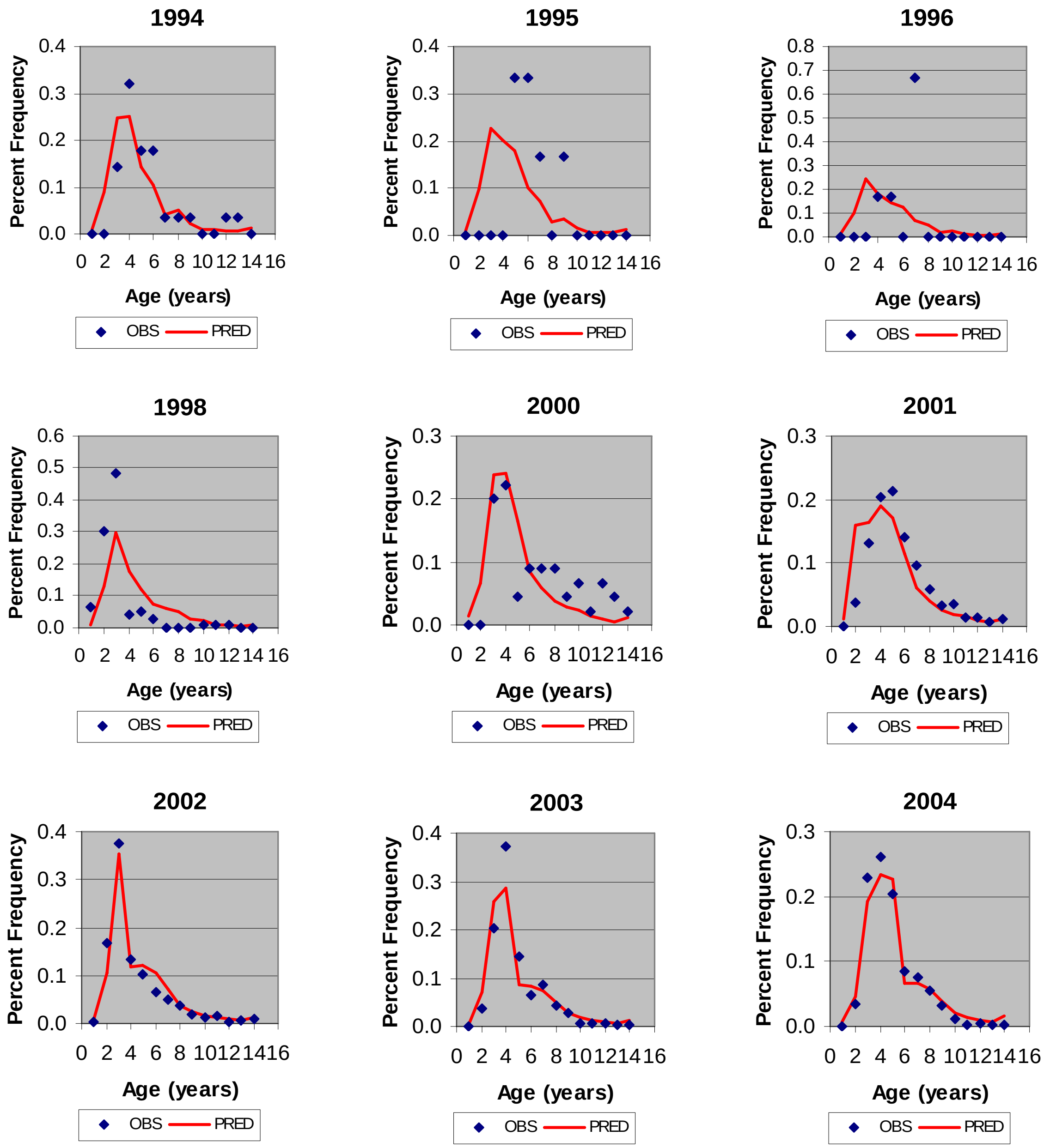



**Figure 3.2.2.1.3** SSASPM base model fits to the age composition of the eastern commercial fishery.

*AGE COMPOSTION COMMERCIAL WEST FISHERY*

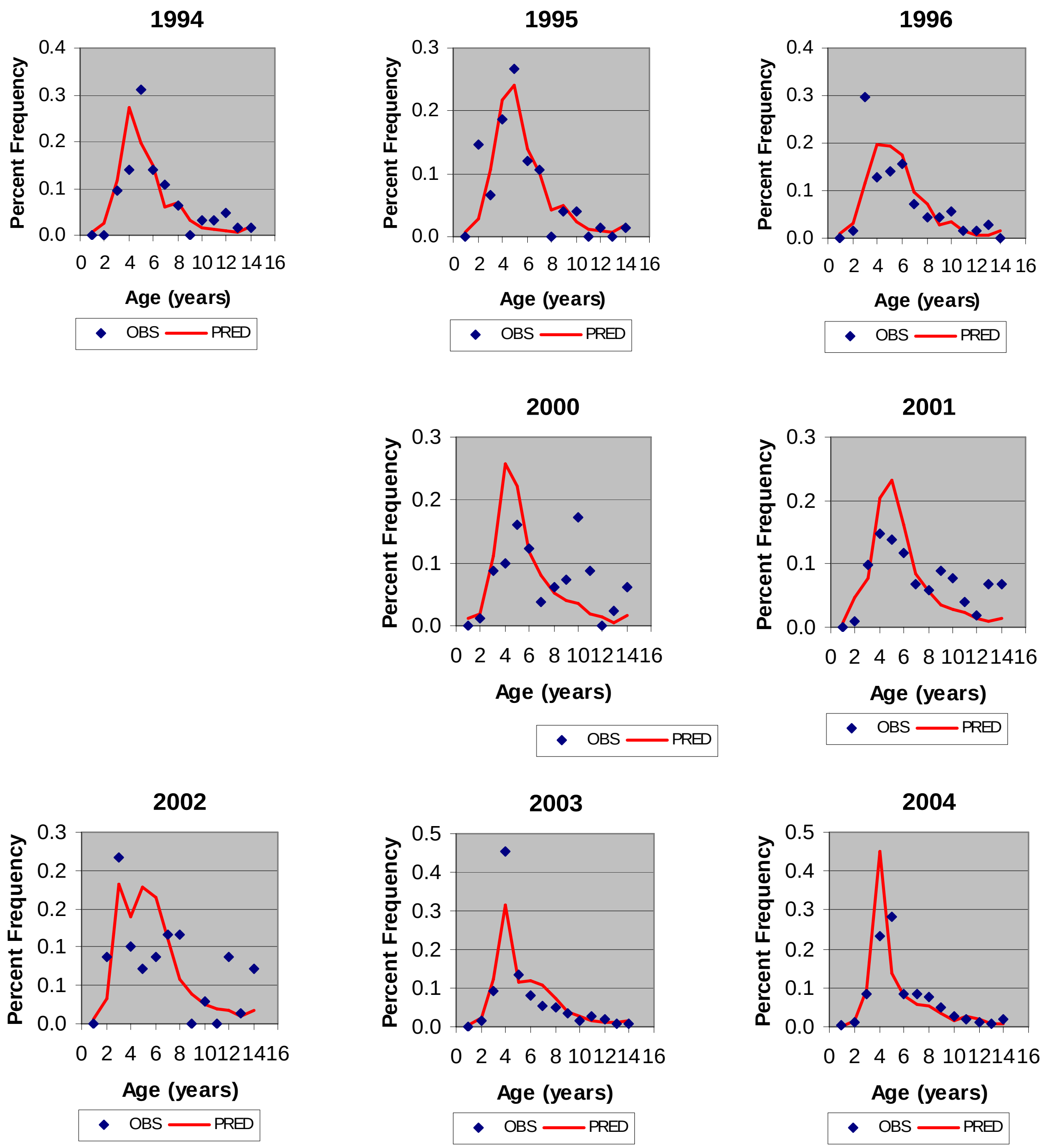



**Figure 3.2.2.1.4** SSASPM base model fits to the age composition of the western commercial fishery.

*AGE COMPOSTION RECREATIONAL FISHERY*

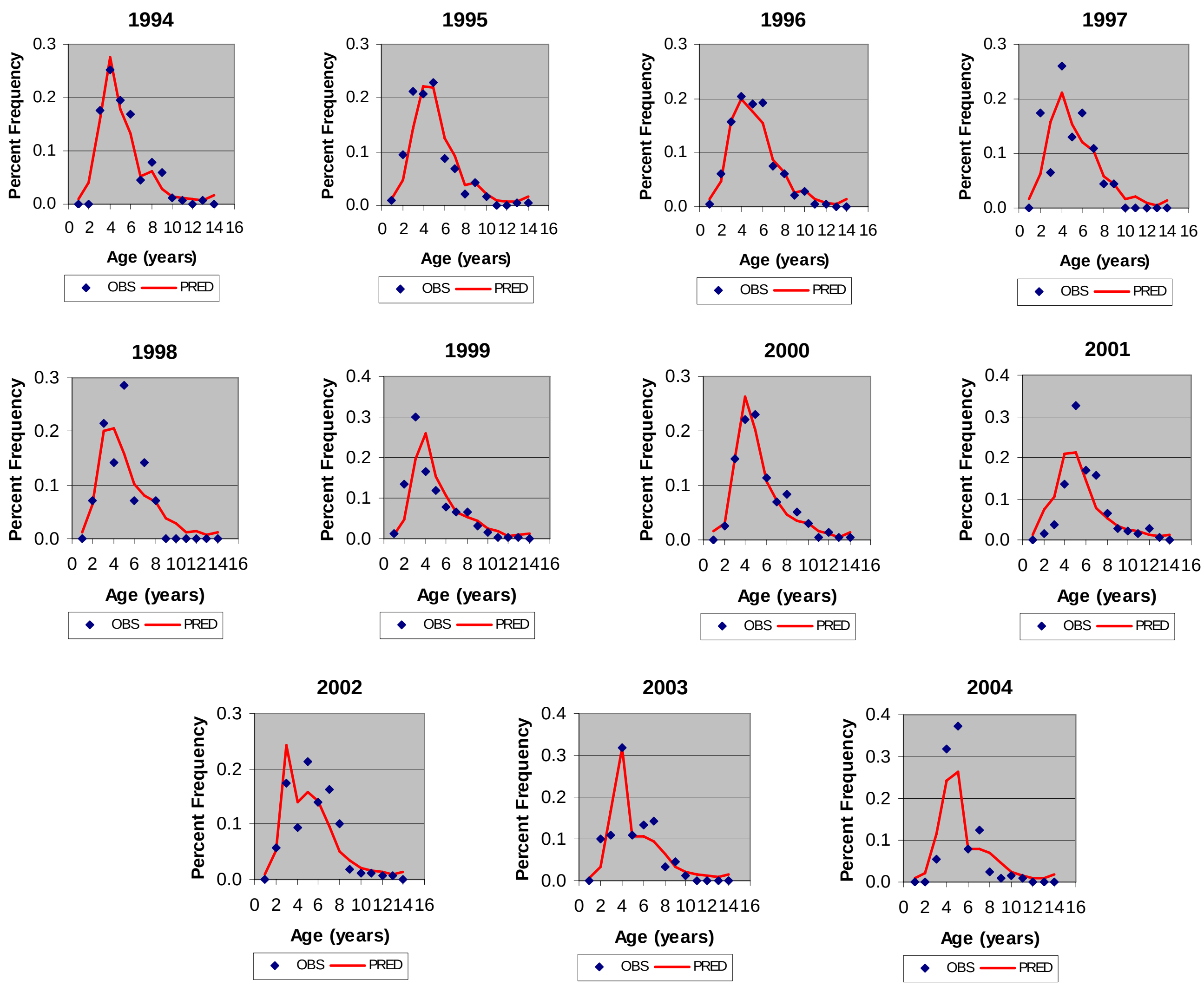



**Figure 3.2.2.1.5** SSASPM base model fits to the age composition of the recreational fishery.

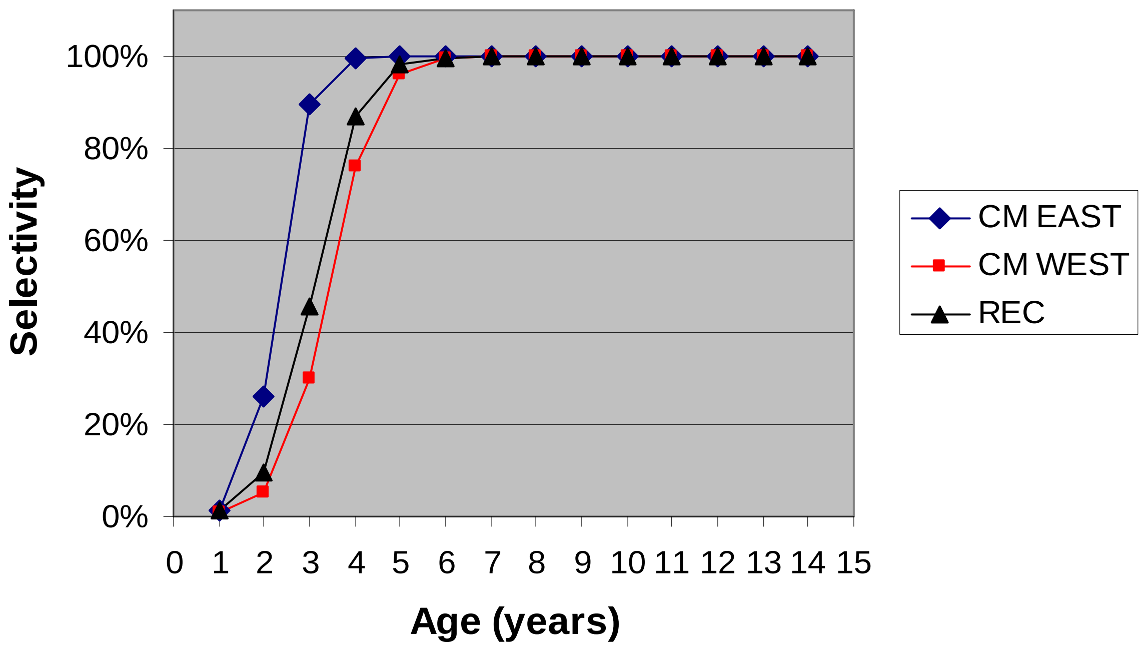



**Figure 3.2.2.2.1.** Estimated selectivity functions for the directed fisheries.

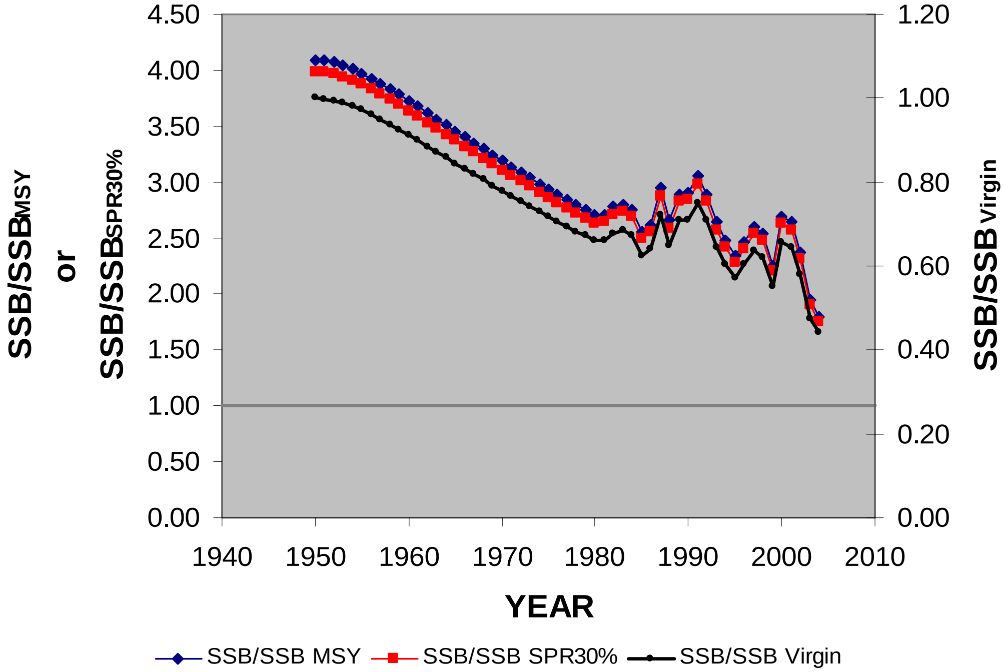



**Figure 3.2.2.3.1.** Spawning stock biomass (SSB) relative to SSB at MSY, SPR30% and virgin condition.

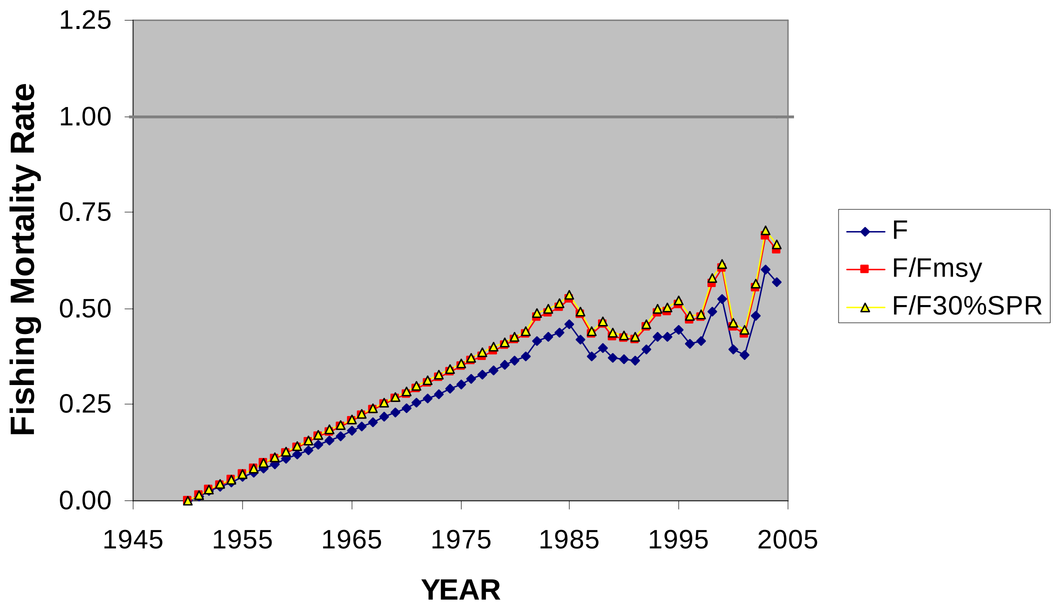



**Figure 3.2.2.4.1.** Fishing mortality rate (F) and F relative to $F_{MSY}$ and $F_{SPR30\%}$..

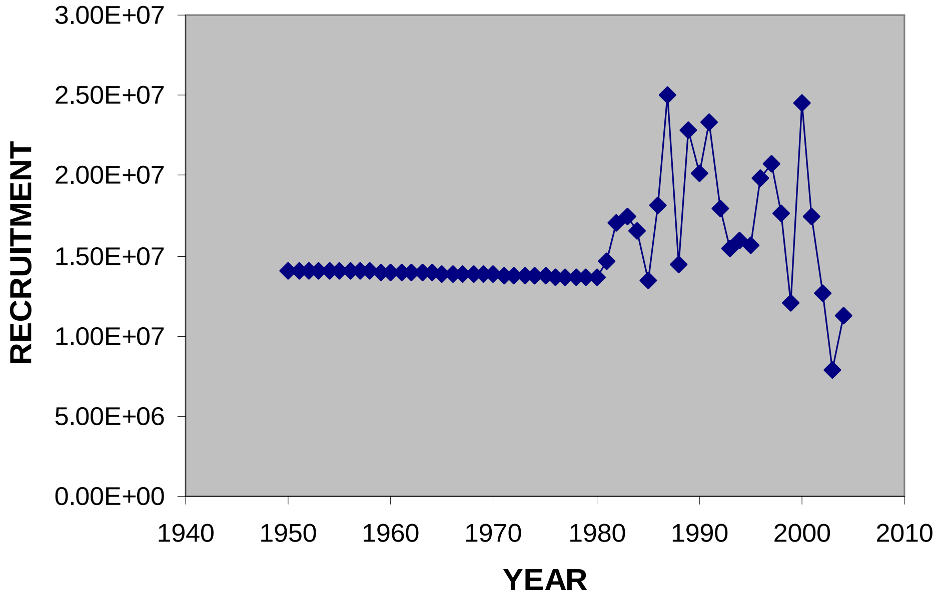



**Figure 3.2.2.5.1**. Annual recruitment (Age 1) estimates.

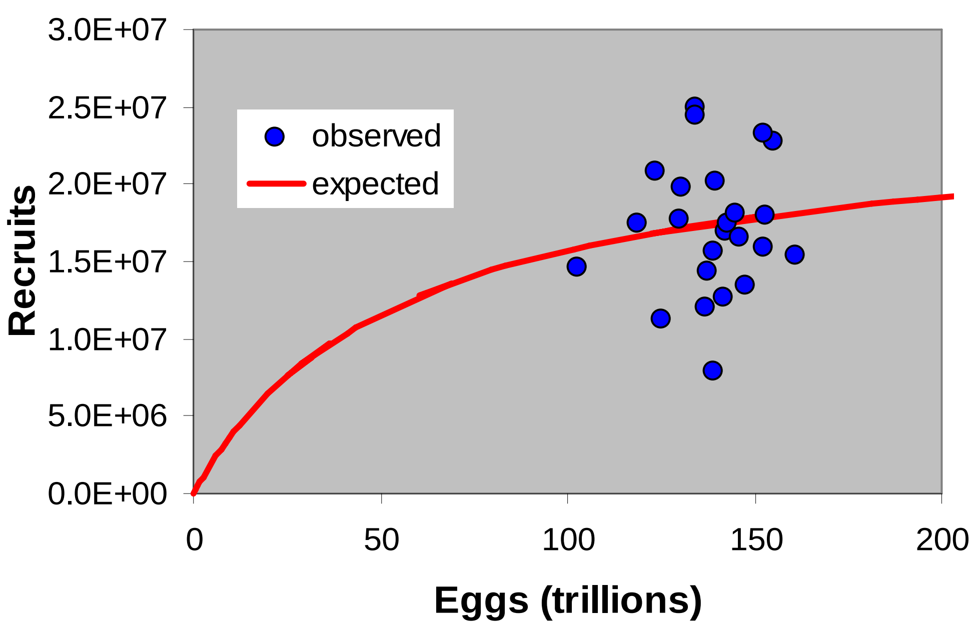



**Figure 3.2.2.5.2.** Spawner-Recruit relationship.

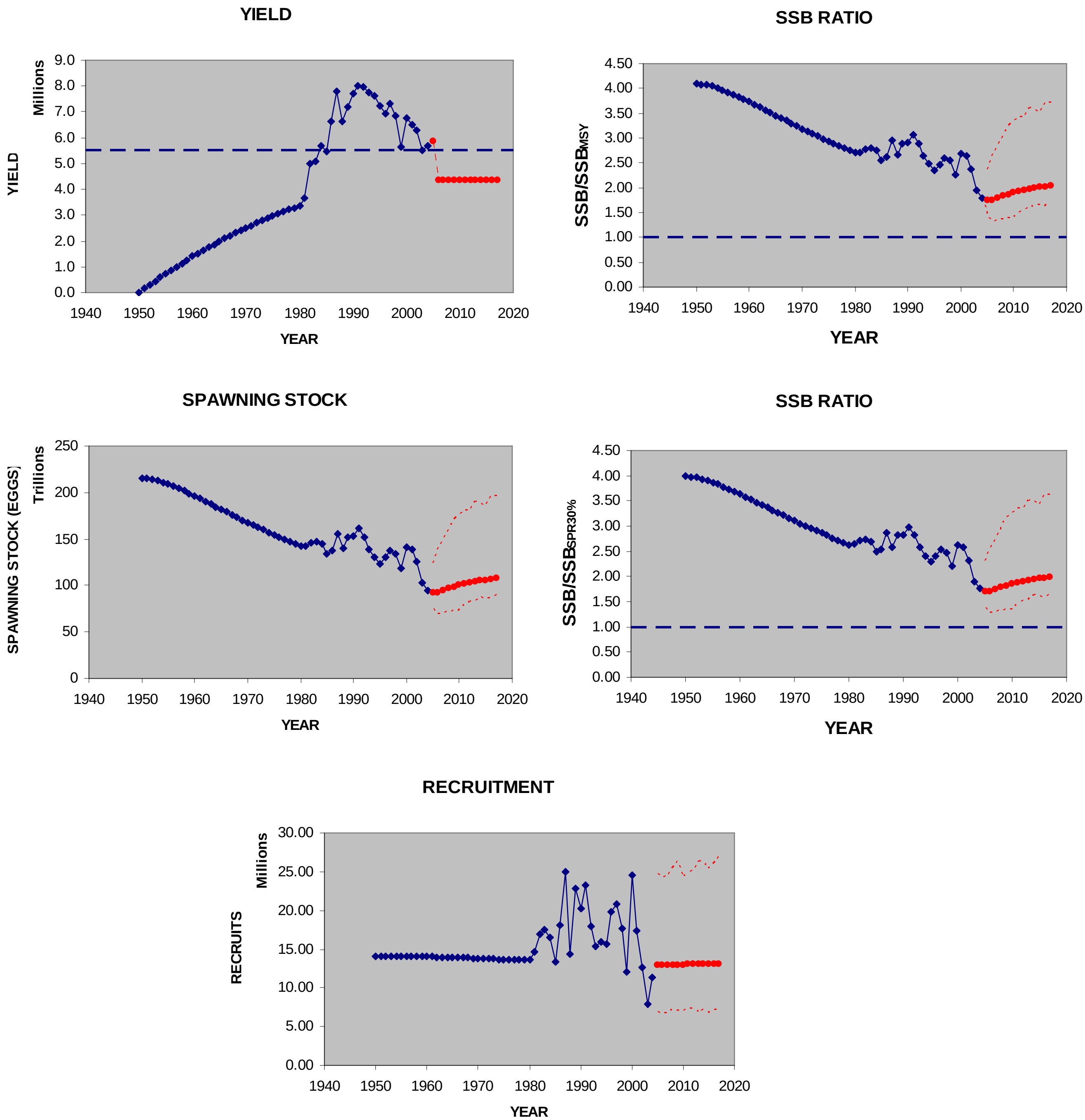



**Figure 3.2.2.9.1.1.** Results of the "Current Yield" projection of the SSASPM base model.

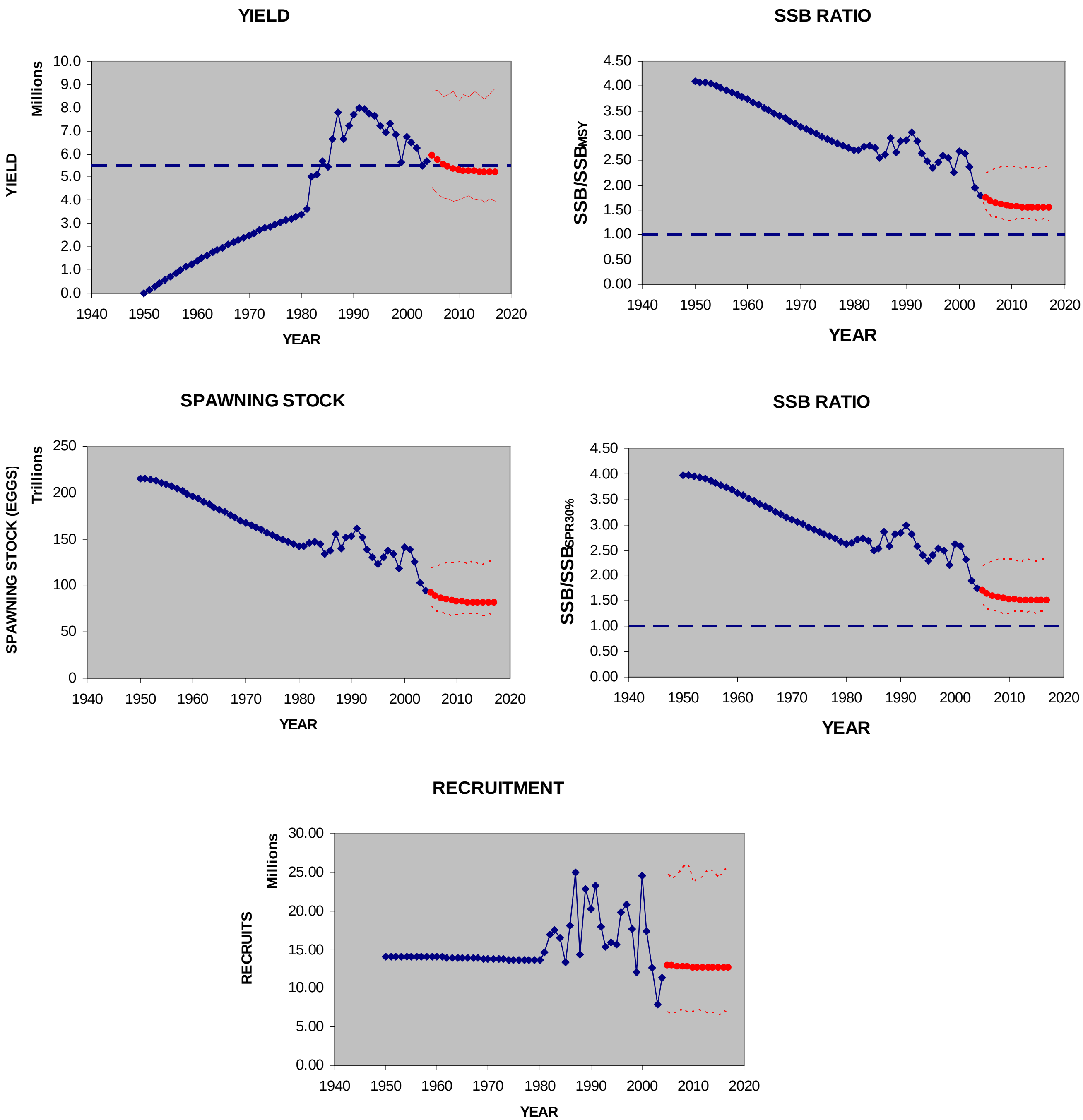



**Figure 3.2.2.9.1.2.** Results of the "Current F" projection of the SSASPM base model.

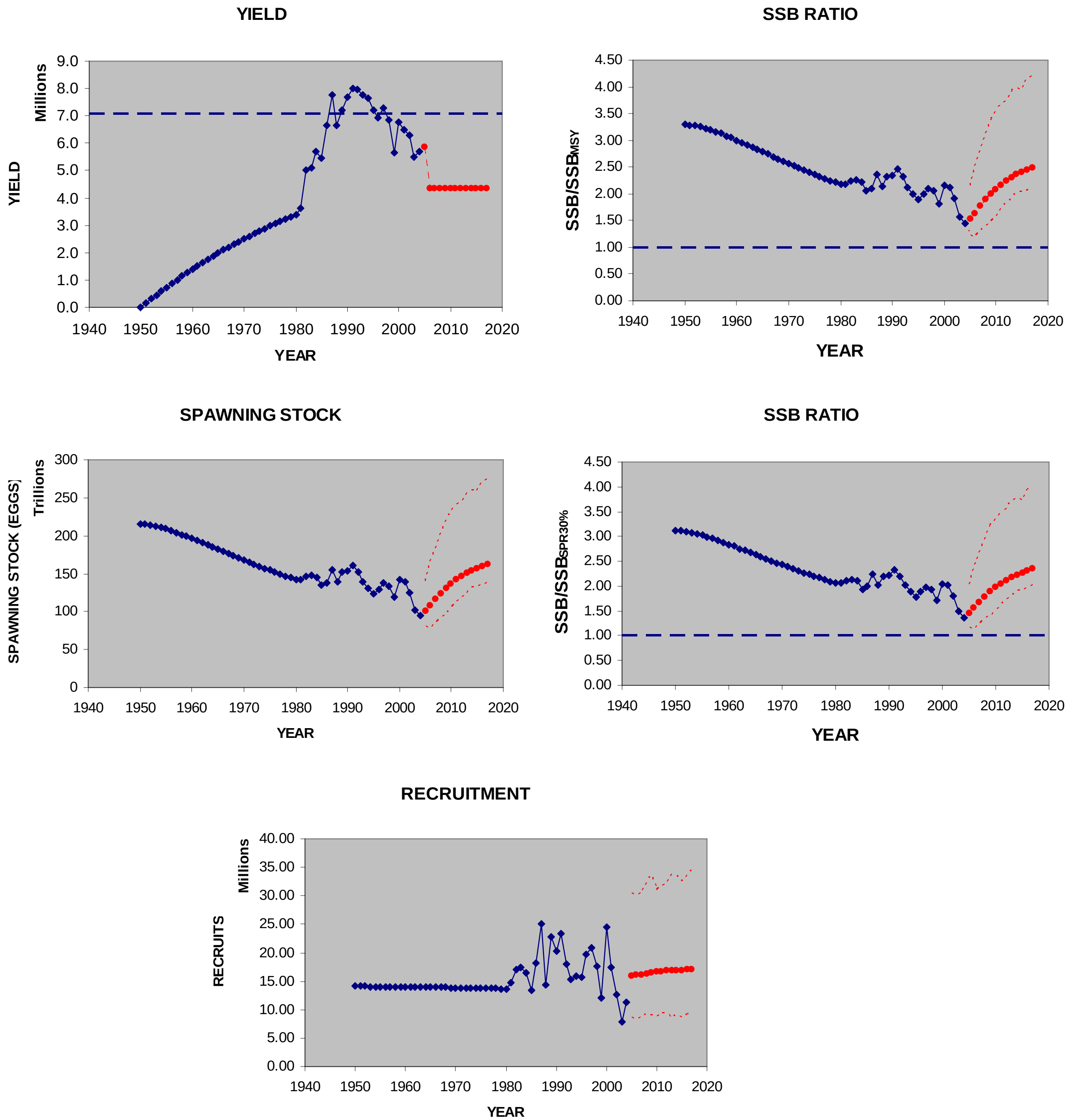



**Figure 3.2.2.9.2.1** Results of the "Current Yield" projection of the SSASPM sensitivity case. This projection uses recruitment parameters estimating using only recent data (1986-2004).

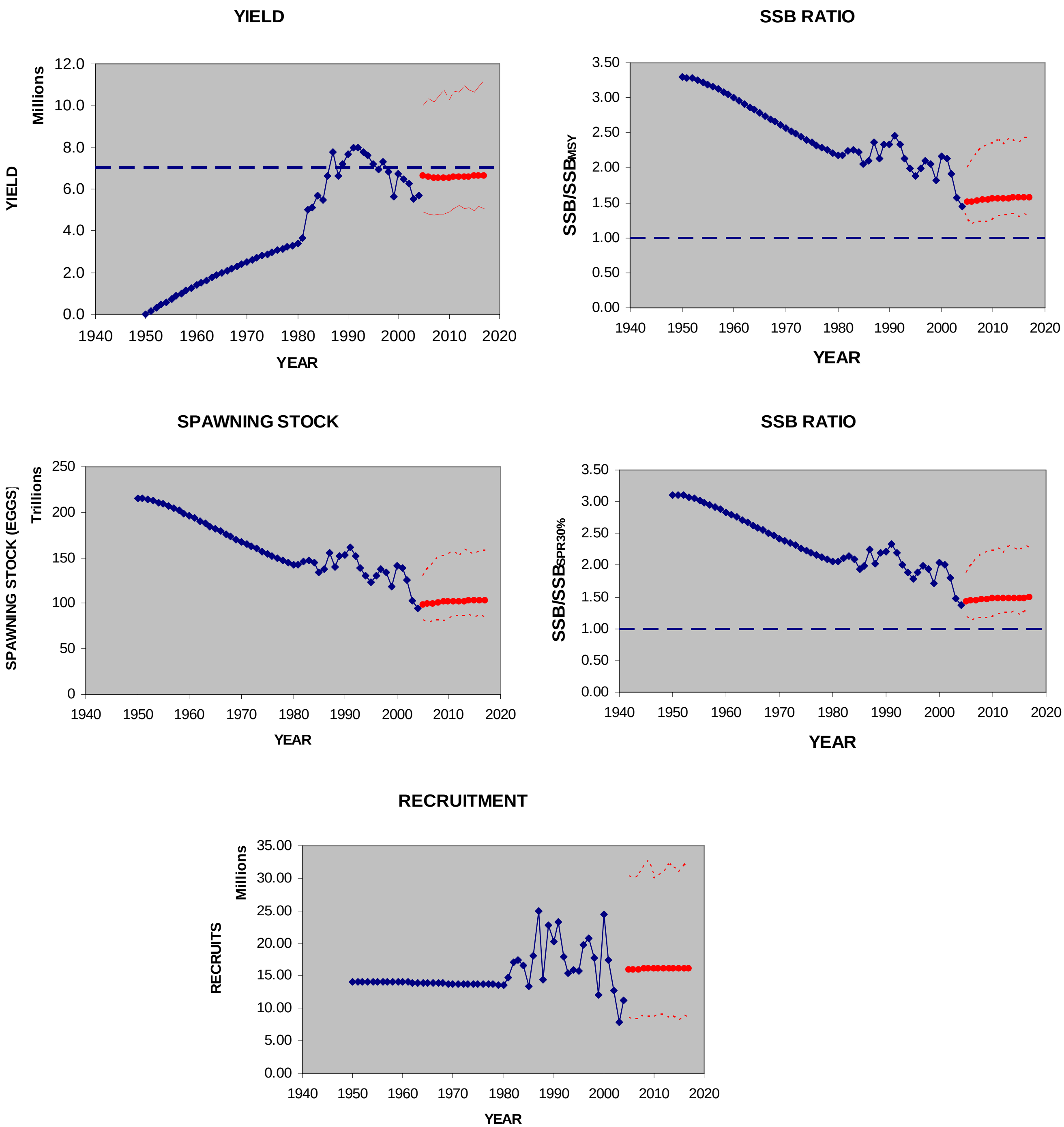



**Figure 3.2.2.9.2.2** Results of the "Current F" projection of the SSASPM sensitivity case. This projection uses recruitment parameters estimating using only recent data (1986-2004).

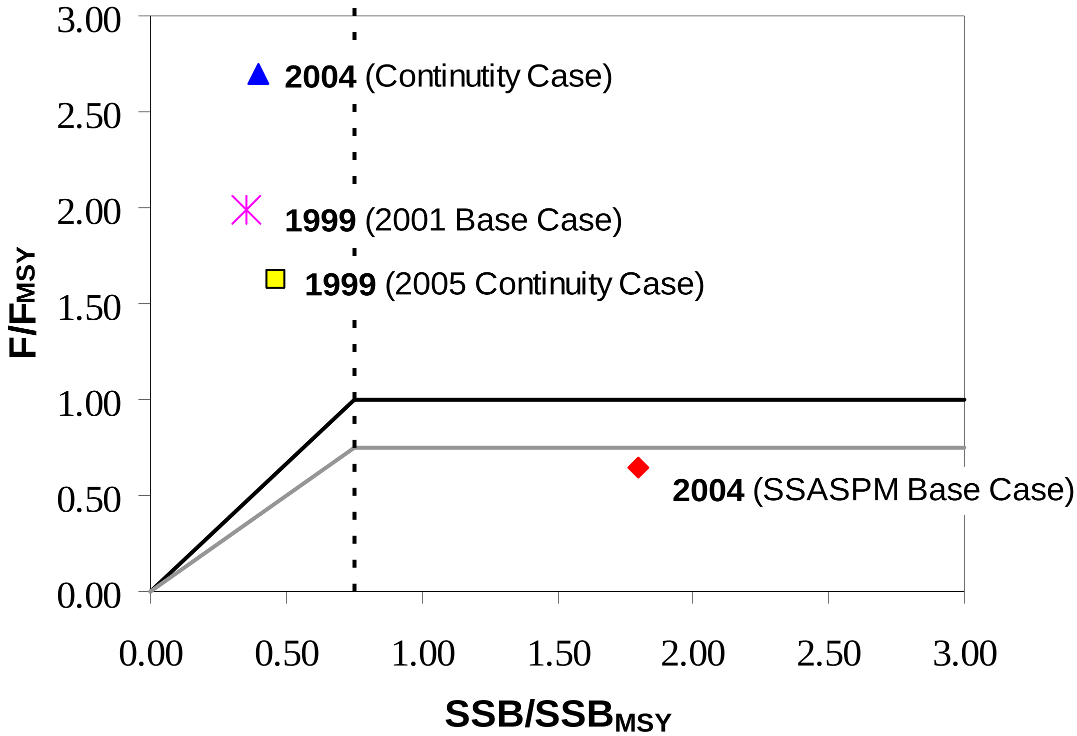



**Figure 4.6.1** Comparison of P-T production and SSASPM model results.